STATUS OF MINERAL RESOURCE INFORMATION FOR THE WIND RIVER INDIAN RESERVATION, WYOMING

David A. Seeland
S. Geological Survey

Earl F. Brauch
U. S. Bureau of Mines

Administrative report BIA-8
1975

CONTENTS

SUMMARY AND CONCLUSIONS

The Wind River Indian Reservation, located in the western half of the Wind River basin in Wyoming, encompasses more than 3,500 square miles and has a resident population of 4,435 members of the Arapahoe and Shoshone tribes within or immediately adjacent to the reservation lands. Owing to current national energy requirements, the potential for further development of fuel resources on the reservation probably never has been greater.

Petroleum and natural gas are the most significant mineral products of the reservation area. Reserves are estimated to exceed 60 million barrels of petroleum and 65 billion cubic feet of natural gas. More than 6 million barrels of petroleum and 13 billion cubic feet of natural gas were produced in 1973. Petroleum production has declined since 1957, the peak year, but revenues of nearly $2.7 million in 1973 were the highest since record-keeping began in 1932. Cumulatively, 183 million barrels of petroleum has been produced through 1973.

Natural gas production and revenues peaked in 1971 when 19 billion cubic feet was produced having a gross value of about $3 million. Production declined more than 5 billion cubic feet from 1971 to 1973; cumulative production amounted to nearly 161 billion cubic feet through 1973.

Probably the greatest potential for resources on the reservation is coal. Coal mining has been dormant in the area for many years, but could be rejuvenated because of the national energy shortage. Four of the five major coal fields in the Wind River Basin are totally or partly within the reservation. Recoverable coal reserves of nearly 15 million tons are calculated for those portions of the four fields within the reservation based on a minimum coal thickness of 5 feet and a 50-percent recovery by underground mining methods. A deterrent to coal mine development could be the competition from large scale, less costly, surface mining operations in other parts of the State.

Gypsum mining and related production or fabrication facilities, such as plants for manufacturing wallboard, warrant study as a method to develop an important mineral potential on the reservation. Large deposits of high-grade gypsum occur on the reservation, and those near rail transportation in the Lander area probably are the most promising for development.

Very large bentonite deposits are found on the reservation, but no commercial grade deposits are known; however, a systematic sampling of deposits over the entire area might reveal commercial deposits.

Approximate boundaries of the arkosic portion of the Wind River Formation near the Wind River Range should be determined as these rocks are similar to the host rocks of the Gas Hills uranium deposits. Samples of Precambrian granites in the mountain ranges should be analyzed for uranium to determine their relative favorability as uranium source rocks.

A geochemical study of stream sediment samples from the Wind River and Owl Creek Mountains might locate metal deposits in these ranges.

Further work recommended includes reconnaissance study of bentonite bearing formations, aeromagnetic surveys for taconite, and a basin analysis of the Wind River Formation to delineate favorable environments for uranium deposits.

INTRODUCTION

The Wind River Reservation (Figure 1 and Figure 2) includes an area of 3,544 square miles in Fremont and southern Hot Springs Counties, Wyoming. Portions of the Owl Creek, Washakie and Absaroka Mountains lie in the northern part of the reservation. The rugged, glaciated, Wind River Range crosses the southwest corner of the reservation. The remainder of the reservation is in the land River Basin, except for a small part extending into the Bighorn Basin. The Wind River flows from the northwest part of the reservation to Riverton, turns north along the east edge and leaves the basin through the Wind River Canyon which cuts directly across the Owl Creek Mountains.

This report was prepared for the Bureau of Indian Affairs by the Geological Survey and the Bureau of Mines under an agreement to compile and summarize available information on the geology, mineral and energy resources, and potential for economic development of certain Indian lands. This evaluation was done primarily from personal communications and researching the literature. The U. S. Bureau of Mines completed an earlier mineral study of the Wind River Reservation in October 1965 (Bolmer and Biggs, 1965).

Principal mineral revenues of the Wind River Reservation are from petroleum and natural gas production. Some sand and gravel is also produced. Iron ore, uranium, and feldspar are being produced elsewhere in Fremont County, Wyoming. Known mineral resources present on the reservation but which are not being produced commercially include bentonite, coal, gypsum, limestone, phosphate, stone, and copper.

ACKNOWLEDGMENTS

Individuals from several government agencies were helpful in providing information for this report. A partial list includes Roger Diedrick, U. S. Bureau of Mines; Gary Glass, Wyoming Geological Survey; Mary Nagashima, James O. Jackson, and Thomas J. Condon, U. S. Bureau of Indian Affairs; and A. F. Czarnowsky and Thomas P. Richmond, U. S. Geological Survey.

LAND STATUS

According to the Bureau of Indian Affairs (Counselman, 1973), the reservation contains a total area of 1,886,268.57 acres. Of this, 1,781,074.31 acres are tribal lands, 103,898.11 acres are allotted lands, and 1,296.15 acres are government-owned lands. Because the allotted and government lands are scattered throughout much of the reservation, this study makes no attempt to delineate these lands from the overall reservation. The study area considered is the entire reservation.

GEOLOGY

Setting

The Wind River Reservation lies in the west half of the Wind River basin, a structural and topographic basin in central Wyoming formed in latest Cretaceous and early Tertiary time, and includes parts of the Wind River, Owl Creek, Washakie and Absaroka Ranges (Figure 2). The Wind River basin is defined by folded and faulted anticlinal uplifts which range from high mountains (Wind River Range on the southwest; Washakie, Absaroka, Owl Creek, and Bighorn Mountains on the north) to low mountains (Granite mountains on the south) and to areas defined entirely by geologic structure (Figure 3). Figure 4 is a generalized geologic map of the reservation and adjacent areas.

The major structural elements of the reservation are the marginal mountain uplifts and the intermontane Wind River basin. Paeozoic and Mesozoic strata along the Wind River Range dip into the basin 12 to 15 degrees. Dips along the Washakie and Owl Creek Ranges are generally into the basin but much less regular, varying from flat to overturned. Generally flat-lying Tertiary strata floor the central part of the basin. The structural relief between the mountains and the basin, on the upper surface of the Precambrian, is as much as 30,000 feet just east of the reservation boundary along he southern flank of the Owl Creek Range.

The pre-Tertiary sedimentary rocks of the Wind River basin total about 17,000 feet. In the western part of the Wind River basin the Paleozoic marine rocks are about 3,000 feet thick (Figure 5A) and represent only a small part of Paleozoic time, although all systems except the Silurian were deposited. Mesozoic rocks in the basin are about four times as thick (Figure 5B, Figure 5C, and Figure 5D) as the Paleozoic rocks. Eastward spreading seas transgressed across the area in Triassic and Jurassic time. In late Jurassic and early Cretaceous time there was complete withdrawal of the seas from the area. In late Cretaceous time, uplift west of the present Idaho-Wyoming boundary shifted the center of sedimentary accumulation eastward. At the end of the Cretaceous there was local tectonic activity representing the beginning of the Laramide orogeny.

Tertiary continental sedimentation deposited as much as 15,000 feet of stream and lake sediments derived from the mountains formed in early Tertiary time during the Laramide orogeny. These rocks are thickest near the north side of the basin (Figure 5E).

Rock Units

The rock units found in the Wind River Reservation have been described in many published papers; these descriptions have been condensed for this report. For further details the reader is referred to the following publications: (1) Precambrian rocks--Smithson and Ebens, 1971; (2) Paleozoic rocks--Keefer and Van Lieu, 1966; (3) Mesozoic rocks -- Love, Johnson and others (1945); Love, Tourtelot (1949); Yenne and Pipiringos (1954); and Keefer and Rich (1957); (4) Tertiary rocks - Love (1939), and Keefer (1965). The nomenclature of the rocks of the reservation are presented in Table 1.

Precambrian

The Wind River Range is composed mostly of Precambrian granite gneisses, augen gneisses and migmatites which are metamorphic or ultrametamorphic rocks typical of old deeply eroded shield areas (Smithson and Ebens, 1971, p. 7080). The presence of iron-formation, sillimanite, and calc-silicate nodules within the granite gneisses shows that at least some of the Wind River Range core was originally sedimentary. The Precambrian rocks of the Owl Creek mountains cover only about 50 square miles and consist of granite and granite gneiss.

In the Washakie Range, just west of the reservation the Precambrian rocks consist of gray and pink granite and granite gneiss cut by thin pegmatite dikes and quartz veins. Schistose rocks are common (Keefer, 1957).

Cambrian

The Cambrian rocks of the Wind River Reservation are represented by a marine sandstone, shale, limestone, sequence. The most generally accepted nomenclature for this sequence is, from the base upward: Flathead Sandstone, Gros Ventre Formation, and Gallatin Limestone. These units thin eastward from about 1025 feet in the Wind River Range to about 775 feet in the Wind River Canyon. In the Wind River Range the Flathead is about 200 feet thick, the Gros Ventre Formation is about 750 feet thick and the Gallatin Limestone ranges in thickness from 265 to 365 feet. These rocks lie unconformably on Precambrian igneous and metamorphic rocks and were deposited during Middle and Late Cambrian time.

Flathead Sandstone.--The Flathead is reddish brown, light-brown and gray fine- to coarse-grained sandstone. The basal beds are commonly conglomeratic and arkosic. The upper beds are shaly.

Gros Ventre Formation.--The Gros Ventre Formation in the Wind River Range can be divided into three units: a lower shale and shaly sandstone unit; a middle limestone unit; and an upper shale and limestone unit. In the Owl Creek Mountains the Gros Ventre Formation is an easily weathered unit of shale, sandstone, and siltstone with some limestone in the upper part.

Gallatin Limestone.--The Late Cambrian Gallatin Limestone consists of upper and lower limestone units separated by a thin shale unit

Ordovician

Bighorn Dolomite.--Ordovician rocks of the Wind River Reservation are represented only by the Bighorn Dolomite which, because of its resistant nature, is probably the most conspicuous Paleozoic unit in the 0wl Creek, Washakie, and Wind River Mountains. In outcrop the Bighorn is 125 to 250 feet thick but it thins to the southeast and is absent in the southeast corner of the reservation.

The basal Lander Sandstone Member is less than 5 feet thick and occurs only at Trout Creek west of Lander, and at Windy Gap, north of Dubois. The Lander Sandstone Member contains an abundant invertebrate fauna of probable Late Ordovician age. The middle and upper members of the Bighorn Dolomite have a combined thickness of 200 to 300 feet. The unnamed middle member is a cliff-forming buff to light-gray massive, granular dolomite which weathers to a distinctive pitted surface. The member thins southward and eastward because of the erosional unconformity at the top of the Bighorn Dolomite. The upper member, named the Leigh Dolomite, is a chalky- white-weathering dolomite that thins southward from 85 feet at the northwest end of the Wind River Range. The unit is also recognized in the Washakie Range.

Devonian

Darby Formation.--Because the Darby Formation lies between two cliff-forming units, the Bighorn Dolomite below and the Madison limestone above, it is commonly poorly exposed. The most conspicuous beds are dark-brown granular dolomites that emit a petroleum-like odor when freshly broken. The Darby consists of thin- to thick-bedded dolomite in the lower part, and siltstone, shale and sandstone interbedded with limestone and dolomite in the upper part. The Darby is thickest in the northwest part of the reservation where it is about 175 feet thick. It thins to the southeast and is absent east of the line between Thermopolis and Fort Washakie.

Mississippian

Madison Limestone.--The Early Mississippian Madison Limestone consists of 500 to 700 feet of cliff-forming carbonate rock in the reservation area. The major part of the formation consists of massive gray limestone and dolomitic limestone with chert beds and nodules. Highly fractured and brecciated zones are conspicuous in the upper part. The more granular beds commonly contain caves and other solution features.

Pennsylvanian

Amsden Formation.--The Early Pennsylvanian Amsden Formation is from 250 to 350 feet thick on the reservation. The lower 100 feet of cliff-forming, white- to light-brown crossbedded to thin-bedded sandstone is the Darwin Sandstone Member which is in part of Late Mississippian age. The upper part of the Amsden is a nonresistant sequence of dolomite, shale, sandstone, and limestone that produces characteristic reddish and yellowish soils. The contact with the overlying cliff-forming Tensleep Sandstone is topographically abrupt but locally is lithologically gradational.

Tensleep Sandstone.-The Tensleep Sandstone of Middle Pennsylvanian age is lithologically very much like the Darwin Sandstone Member of the Amsden Formation. It is a light brown to white, massive to crossbedded sandstone. Many outcrops weather brown or reddish brown and from a distance appear nearly black. The thickness of the Tensleep on the reservation ranges from about 200 to about 400 feet. The formation is mostly of marine origin but vertebrate tracks have been reported in it near Lander, suggesting at least temporary subaerial conditions.

Permian

Park City Formation.-- McKelvey and Carswell (1956) and McKelvey and others (1956), suggested that the Permian sequence be divided into four major rock groups: red beds; carbonate; mudstone, chert, phosphorite; and sandstone. Respectively, these are then assigned to the Goose Egg Formation, Park City Formation, Phosphoria Formation and Shedhorn Sandstone. The name Park City Formation is used here because the Permian in the Wind River Reservation consists primarily of carbonate rocks.

The Park City Formation in the western Wind River Basin consists of 200 to 300 feet of limestone, dolomite, dolomitic siltstone, shale and chert. The shales and siltstones are locally phosphatic. The phosphatic rocks form two distinct zones on the east flank of the Wind River Range near Lander and have been referred to as the lower and upper phosphate zones by Condit (1924) and King (1947) and as units B and D by Sheldon (1957). The zones are 1 to 2 feet thick and contain from 15. 2 to 29.7 percent P_20_5.

Triassic

Dinwoody Formation.--The Dinwoody Formation is a marine Early Triassic unit that in the reservation area consists of a 25- to 50 foot basal unit of silty limestone, gray crystalline limestone and greenish-brown to gray shales, and an upper unit of as much as 100 feet of calcareous siltstone, silty limestone, crystalline limestone, and some shale. The Dinwoody is 50 - 150 feet thick in the area and thins eastward.

Red Peak Formation.--The Red Peak Formation of thin-bedded red siltstone, red shale, and red silty sandstone is a continental red-bed unit deposited after retreat of the Dinwoody sea. The Red Peak is 800 to 1000 feet thick in the area and thins eastward.

Alcova Limestone.--The Alcova Limestone is pink to gray, finely crystalline limestone from 5 to 15 feet thick although it is absent in the extreme northern part of the area.

Crow Mountain Sandstone.--The Crow Mountain Sandstone is cross bedded light brownish red to gray fine- to medium-grained sandstone that generally contains rounded, frosted sand grains.

Popo Agie Formation.--The Popo Agie Formation consists of red sandstone, shale, and siltstone. Abundant analcite and thin beds and lenses of conglomerate composed of granules and pebbles of limestone, claystone, and marlstone, pebbles, and reptilian bone fragments occur in the upper part (Richmond and Murphy, 1965).

Triassic(?) and Jurassic(?)

Nugget Sandstone.--The Lower Jurassic Nugget Sandstone consists of pinkish-white, fine- to very-fine grained, large-scale crossbedded sandstone. A thin siltstone or shale is present at the base. The formation is as thick as 300 feet, thins to the northeast, and is absent in the northern part of the area.

Jurassic

Gypsum Spring Formation.--The upper part of the Middle Jurassic gypsum Spring Formation consists of interbedded red siltstone and gray limestone. The lower one-half of the unit is mainly white, bedded gypsum and anhydrite.

Sundance Formation.--The late Jurassic Sundance Formation contains interbedded sandstone, shale, and limestone deposited in a marine environment. Sandstone that is fine to medium grained, crossbedded, and glauconitic is more abundant in the upper part. The lower part 11 has more abundant gray to green shale. Oolitic limestone is found throughout the unit. The Sundance thickens westward and is 250 to 350 feet thick in the reservation area.

Morrison Formation.--The Morrison Formation is a series of fluvial siltstone, claystones, shales, and sandstones. The proportion of sandstone decreases from greater than 50% and the proportion of varicolored shale increases to greater than 80 percent from southeast to northwest across the reservation (Peterson, 1972). The Morrison contains many of the well-known dinosaur-bearing beds of the Rocky mountain region.

Cetaceous

Cloverly Formation.--The Early Cretaceous Cloverly Formation consists of light-brown to brown sandstone ("rusty beds") at the top, pale-purple and light-green claystone in the middle, chert pebble conglomerate at the base. The thickness of the unit ranges from 250 to 450 feet. The "rusty beds" were deposited in coastal plain and shoreline environments. The remainder of the unit was deposited in an environment that was entirely continental.

Thermopolis Shale.--The Early Cretaceous Thermopolis Shale consists of unnamed upper and lower black shales and a named medial member, the Muddy Sandstone--a gray thin-bedded sandstone. The upper black shale member grades into the overlying siliceous Mowry Shale. The unit ranges in thickness from 320 to 450 feet.

Mowry Shale.--The Mowry Shale consists of hard black siliceous shale with a-few sandy beds, and many thin bentonite beds. The Mowry is the uppermost unit of the Early Cretaceous.

Frontier Formation.--The Late Cretaceous Frontier Formation is an important oil- and gas-producing formation in many Wyoming fields. It consists of alternating gray to black shale and gray sandstone with a few thin tuff and bentonite beds, and ranges in thickness from 600 to 1000 feet. The unit is resistant to weathering and usually cross out as ridges.

Cody Shale.--The Late Cretaceous Cody Shale can be divided into a lower shaly member and an upper sandy member. The Cody is easily weathered, in contrast to the underlying and overlying formations, and commonly forms broad, flat, soil-covered valleys. The lower member consists of gray to black silty shale that becomes siltier and sandier toward the top. The upper member consists of thin-bedded calcareous sandstone and siltstone interbedded with minor amounts of gray to black fissile shale. The Cody shale ranges widely in thickness, from 2500 to 5000 feet, partly because its plastic nature permits tectonic thinning and thickening.

Mesaverde Formation.--The Mesaverde Formation in most places can be divided into a basal sandstone of beach origin, and an overlying terrestrial unit of variable lithology including sandstone, siltstone, shale, carbonaceous shale, and coal. Individual beds are commonly lenticular and not more than a few feet thick. The upper member is a white sandstone commonly forming cliffs and ledges. Where present the Mesaverde ranges in thickness from 1000 to 2000 feet but it is absent in the southwest part of the area.

Meeteetse Formation.--The Meeteetse Formation of Late Cretaceous age can be divided into a lower banded unit and an upper massive lenticular sandstone unit. The lower part of the Meeteetse is interbedded sandstone, siltstone, shale, and coal. Large, spherical concretions up to 3 feet in diameter weather out of the lower sandstone unit. Some of the coal beds are of minable thickness. Plant remains and dinosaur bones are found in the Meeteetse. The upper part of the Meeteetse is a massive lenticular sandstone unit ranging in thickness from 0 to 300 feet. The formation is absent in the western and southern parts of the area; elsewhere it is as much as 1400 feet thick.

Lance Formation.--The Lance Formation of latest Cretaceous age consists of a basal sandstone with lenses and thin beds of conglomerate overlain by gray to black claystone and shale. The upper unit contains sandstone and conglomerate beds, and a few thin partings of coal. The Lance attains a maximum thickness of 1200 feet. It thins from north to south, and is absent in the western and southwestern parts of the area.

Tertiary

Fort Union Formation.--On the margins of the Wind River Basin the Fort Union Formation of Paleocene age unconformably overlies the Late Cretaceous Lance Formation. The unconformities extend only a slight distance into the subsurface; in the central basin areas deposition was continuous from Late Cretaceous to Paleocene time. The Fort Union can be divided into two parts: a lower sequence of interbedded sandstone conglomerate, shale, and carbonaceous shale of fluviatile origin and an upper sequence of shale, siltstone, claystone, and sandstone. Keefer (1961) divided the upper part of the Fort Union into the Waltman Shale and the Shotgun Butte Members.

Indian Meadows Formation.--The Indian Meadows Formation, of earliest Eocene age, crops out on the northern margin of the Wind River Basin, and is impossible to distinguish from the overlying Wind River Formation in the subsurface. The Indian Meadows consists of banded red, gray and tan, clays and silts, plus coarse conglomerates that originated as stream channel and alluvial fan deposits. Masses of Paleozoic rock, more than ¼ mile long, are found within the formation and may be landslide deposits or may be remnants of thrust sheets formed during uplift of the Owl Creek and Washakie Ranges. The Indian Meadows is absent along the southwest side of the basin but may be several thousand or more feet thick in the subsurface along the north side of the basin.

Wind River Formation.--The Wind River Formation of Early Eocene age is exposed over a greater part of the surface area of the Wind River Indian Reservation than any other geologic unit. The Wind River Formation originated during the period following uplift of the Wind River, Washakie and Owl Creek Ranges in earliest Eocene and is composed of debris deposited in alluvial fans near the mountains, stream channels, and flood plans, lakes, and swamps farther out in the basin. Rock types include alternations of red and green siltstone, claystones, sandstone and conglomerate. The Wind River conglomerates contain abundant Precambrian rock fragments that record exposure of the igneous and metamorphic cores of the ranges bordering the basin. These conglomerates are in contrast to those of the formations which contain conglomerate derived from Mesozoic rocks. Conglomerate in the upper part of the Indian Meadows is coarse and consists of fragments of Paleozoic rocks.

The thickness of the Wind River ranges from a few feet at the basin margin to at least 6,000 feet in the northern part of the reservation.

Aycross Formation. The Aycross Formation, a middle Eocene unit found in the northwest corner of the reservation south of the Washakie Range, unconformably overlies the Wind River Formation. The Aycross is composed of tuff, claystone, shale, and sandstone. Conglomerates composed of volcanic clasts are conspicuous locally. Lateral changes in lithology and thickness are rapid.

Tepee Trail Formation.--The Tepee Trail Formation of Middle and Late Eocene age unconformably overlies the Aycross Formation in the southern Absaroka mountains in the extreme northwest corner of the area and consists of greenish andesitic volcanic conglomerates, sandstones, shales, tuffs, flows, and thin carbonaceous beds. The unit is about feet thick.

Unnamed tuff.--In the northeast part of the reservation on the south flank the Owl Creek Mountains, an unnamed Middle and Late Eocene unit of tuff and volcanic conglomerate with some limestone has been mapped. The unit is in part the same age as the Tepee Trail Formation.

Wiggins Formation.--The Wiggins Formation of Oligocene age overlies Tepee Trail Formation and forms the spectacular cliffs and peaks, such as the Ramshorn, on the southern margin of the Absaroka Mountains. It is about 1000 feet thick and is composed of volcanic conglomerate and breccia interbedded with tuffs. The conglomerates thicken and the size of the clasts increase toward the north and northwest indicating that the vents which produced the volcanic detritus lay to the north (Love, 1939, p. 110-111).

Quaternary

Pleistocene Glacial Deposits.--Pleistocene till and outwash gravel representing five glacial advances are present in the southwest part of the area along the northeast flanks of the Wind River range. The oldest glaciation is indicated only by pebble, cobble, and boulder gravel. The younger glaciations are represented by both outwash gravel and progressively better developed morainal forms consisting of compact, stony, silty sand.

Holocene Deposits.--Holocene sediments include unconsolidated pebble, cobble, and boulder gravel, sand, silt, and clay deposited on flood plains, as slope wash, as terrace, pediment, landslide, and colluvial deposits.

Geologic Structure

Mountain Structure

Wind River Range.--The Wind River Range, one of the major mountain lifts of Wyoming, trends across the southwest corner of the reservation (Figure 2). The structures of the Precambrian granitic and metesedimentary core rocks of the range have been little studied but faults, shear zones, dikes, and folds generally have northwest, north, or northeast trends. Keefer (1970, p. D12) states that the latest movements on northwest-trending structures may be of Laramide age and east- and northeast- trending structures may have been produced Precambrian deformations.

The east flank of the range is formed by Paleozoic and Mesozoic rocks dipping 12º to 15º eastward into the Wind River basin. Cherty limestones of the Park City Formation form the outermost of a series of flatirons along the range and less resistant Mesozoic rocks form hogbacks and valleys in the foothills. The range is asymmetrical and appears to be bounded on the west by a major high angle reverse fault (Blackstone, 1948, p. 73).

Washakie Range.--The Washakie Range forms the north margin of the Wind River Basin in the northwest corner of the reservation (Figure 2). Love (1939, p. 5), describes it as "a series of faulted folds, enechelon, beginning with the eastern flank of Black Mountain, extending 70 miles northwest . .." The folds are asymmetric toward the south and southwest and although the southern margin of the range is covered by Tertiary strata, each fold is probably bounded by a thrust fault (Keefer, 1970, p. D14). The larger anticlines of the range have cores of granite and granitic gneiss.

Owl Creek Mountains.--The Owl Creek Mountains extend eastward from near the east end of the Washakie Range to the southwest end of the Bighorn Mountain (Figure 2). They can be divided into two parts. West of Mexican Pass (12 miles west of Wind River Canyon) they consist of northwest-trending anticlines and northeastward-tilted fault blocks. East of Mexican Pass the Owl Creek mountains consist of one large east-west anticlinal uplift. The Owl Creek Mountains west of Mexican Pass, together with the Washakie Range, form a structural unit disrupted only by the southward extension of volcanic rocks of the Absaroka Mountains.

In the northeast part of the reservation rocks on the south flank of the Owl Creek Mountains are steeply dipping to over turned and override the Tertiary rocks of the Wind River basin along a series of reverse faults.

Structural relationships along the basin margin are difficult to interpret, however, because the Wind River Formation laps onto the foot of the Owl Creek uplift. In the north central part of the reservation a series of northwest-trending anticlines plunge southeastward into the basin. On the north side of the mountains the rocks dip gently into the Big Horn Basin.

Absaroka Mountains.--The Absaroka Mountains, in the northwest part (Figure 2) of the reservation, consist of nearly flat-lying volcanics of the Teepee Trail and Wiggins formations. The softer rocks have been eroded by streams and glaciers to form spectacular pinnacles and ridges.

Basin structures

Wind River Basin.--Figure 3, a generalized structure contour map of the Wind River basin, shows that the deepest part of the basin is near the north side adjacent to the Owl Creek Mountains. A series of oil-productive anticlines parallel the Wind River Range, from just north of Lander to Black Mountain. About 6 miles east of this anticlinal trend is another series of anticlines, about 30 miles long, that dies out to the south. The central part of the northwestern arm of the Wind River basin may actually lie beneath the Washakie Range (Keefer, 1970, p. D23). The deepest part of the basin lies just south of the Owl Creek Mountains in the northeast corner of the reservation.

Many of the anticlines are asymmetrical; the southwest limbs are the steepest and are broken by eastward and northeastward dipping thrust faults. A major thrust fault known as the south Owl Creek Mountains fault dips northward about 70 along the north edge of the basin and has a much as 20,000 feet of stratigraphic displacement (Keefer, 1970, p. D18).

MINERAL RESOURCES

Introduction

In this paper, potential resources refer to a combination of conditional resources (identified but currently subeconomic) plus hypothetical resources (undiscovered but in known district) plus speculative resources (undiscovered resources in undiscovered districts). These resource categories are diagrammatically presented in Figure 6. The stratigraphic occurrence of potential mineral resources of the Rind River Reservation are summarized in Table 2.

Energy Resources

Petroleum and Natural Gas

In 1884 the first commercial oil well in Wyoming was drilled near Lander at Dallas dome, just south of the Wind River Reservation. The first oil discovery on the reservation took place 25 years later (1909) at the Plunkett field, north of Lander (Figure 7).

Revenue from petroleum and natural gas is the major source of tribal income (Table 3, Table 4, and Table 5). For the fiscal year ending June 30, 1974, royalties, bonuses, rentals, and fees from oil and gas brought more than $4,073,000, according to figures provided by the Bureau of Indian Affairs, Branch of Real Property Management. More than $211,000 also was paid to individuals during the same period. Approximately 900 oil and gas leases cover 450,426 acres of tribal and allotted lands.

On the reservation, 397 oil and 51 gas wells produce from tribal lands, and 44 oil and 1 gas well produce from individual lands. Wind River basin petroleum and natural gas production is from 17 different formations that range in age from Mississippian to early Eocene and range in depth from less than 500 feet to three miles.

Most production in the basin is from structural traps, and many of the fields produce from multiple zones. Principal reservoirs are in the Tensleep, Park City, Cloverly, Muddy, Frontier, Lance, and Fort Union Formations. Sandstone is the host rock for all but those in the Park City (Phosphoria) formation.

Geologic controls.--Most of the fields produce from Laramide anticlinal structures (Bolmer and Biggs, 1965; Thompson, 1958; Keefer, 1969; and Stauffer, 1971).

In pre-Laramide time (pre-latest Cretaceous time), fluid hydrocarbons migrated eastward through the westward dipping sedimentary strata. (Keefer, 1969, p. 1860) suggests that the transmission of fluids was locally blocked in the western and west-central parts of the basin accounting for the high yield and multiple pay zone fields that region. Relative favorabilities of the rock units of the reservation are listed in Table 2.

The anticlines that account for almost all of the present production the reservation were the result of compressional stresses that started in latest Cretaceous time, increased in intensity through the Paleocene, and culminated in earliest Eocene time. The resulting folds and faults show a strong northwest alignment.

Reserves.--Accurate data for petroleum and natural gas reserves are not available, but more than 60 million barrels of petroleum and 65 billion cubic feet of natural gas are estimated as reserves. The petroleum estimate is based on 10 years of production at the 1973 rate, and the natural gas estimate is based on 5 years of production at the 1973 rate. The 5-year rate was used for natural gas because of the rapid decline in production from 1971 to 1973.

Potential resources.--Using Stauffer's (1971, p. 655) figure of 944,000,000 barrels of possible undiscovered oil in place in the Wind River Basin-Casper arch area, one can calculate, based on the volume of sedimentary rocks on the reservation, that about 350,000,000 barrels of possible undiscovered oil exists on the reservation. Stauffer states that with present technology a conservative estimate is that about 10 percent of the oil in place is recoverable. This indicates about 35 million barrels of recoverable oil is present on the reservation.

Most of the known anticlines have been drilled and most discussions of the petroleum geology of the Wind River basin conclude that stratigraphic traps have the highest potential for the discovery of additional oil and gas. Stauffer (1971, p. 644) states that the best prospects for future production are in stratigraphic traps in Cretaceous marine sandstones, an example of which is the Grieve field in the southeastern Wind River Basin which has produced nearly 30 million barrels from Muddy Sandstone.

Stratigraphic traps containing mostly gas accumulations probably also exist in the Cretaceous Lance Formation and in the Tertiary Fort Union and Wind River Formations. The Fort Union and Wind River may contain important quantities of gas since they make up about one-half the sedimentary volume of the basin.

Thompson (1958, p. 323) suggested that there are numerous pinchout possibilities in the Morrison and Cloverly Formations in the western part of the basin.

Exploration targets.--Keefer (1969, p. 1860-1861) summarized potential exploration targets in the Wind River Basin. Those pertinent to exploration on the Wind River reservation are the following:

1) Granular dolomite beds at the base of the Darby Formation are beveled by the Madison Limestone in the southeastern part of the reservation (Keefer and Van Lieu, 1966, Figure 11) and may provide potential unexplored traps for oil and gas. The wedge edge of the Bighorn Dolomite may provide similar traps in the eastern part of the reservation on a line from near Lander to Thermopolis.
2) Irregularities in the contact between the Tensleep Sandstone and the overlying Park City Formation may have trapped petroleum and this mode of entrapment may be augmented by permeability variations in the Tensleep.
3) Pre-Laramide structures or topography may govern the distribution of strandline sand bodies (Muddy Sandstone Member) in the Thermopolis Shale. Keefer (1969, Figure 8) shows such a structure from the southeast to the northwest corner of the reservation.
4) Variations in thickness and lithology of sandstone units in the Frontier Formation may provide stratigraphic traps.
5) Thickness variations and unconformities within post-Frontier pre-Lance strata may provide stratigraphic traps. These features may have developed in response to gentle pre-Laramide warping.
6) In the southeast corner of the reservation, sandstone and shale intertongue along the Cody-Mesaverde contact. The sandstone tongues are potential traps, particularly if they cross anticlinal noses.
7) Oil seeps, although the earliest of petroleum exploration guides, may still be of use in the Wind River basin. Basinward connections with undepleted oil and gas reservoirs may be related to fault zones, certain stratigraphic units. or unconformities.

Keefer (1969, p. 1862-1863) also points out that favorable porosity and permeability are probably present to depths of 15,000 - 20,000 feet. Only the uppermost Cretaceous and lower Tertiary strata have been explored in the central part of the basin. The Frontier and older rocks are untested in an area of 3,500 square miles, and in about 2,000 square miles of the area, the Frontier and older reservoirs are less than 15,000 feet deep. This latter area includes much of the eastern part of the reservation (Figure 8).

A thesis by Robert F. Holmes, Jr. (1959) includes cross sections that reveal a fold in the Sundance Formation. If the fold is followed southward, a trap may have developed in the Sundance or lower beds in approximately SW¼ sec. 34, T. 6 N., R. 6 W.

David C. Kisling's thesis (1962) mentions the Bargee anticline with a minimum closure of 250 feet, in T. 7 N., R. 1 W. as not being condemned by the one well drilled on the southeastern flank into the Crow Mountain Sandstone. The narrow structure is breached higher in the section by the Gypsum Springs Formation.

Richard S. Ellerby (1962) contends that "the only potential site for the accumulation of oil and gas is in the Willow Creek anticline." The anticline is in secs. 25, 26, 35, and 36, T. 4 N., R. 4 W., Fremont County. After 1962 the structure was drilled to test the Tensleep in NE¼NW¼ sec. 35, T. 4 N., R. 4 W.; results were discouraging.

Promising production zones have been tested at the Lander (Hudson) anticline. The deeper Madison Limestone does not appear to hold great promise, but available records reveal that there has been only one test hole in the upper half of the formation in this area. That hole. drilled in NW¼ SE¼ sec. 24, T. 2 S., R. 1 E., flowed at a rate of more than 1,000 barrels of water per day from a drill stem test. In this area the top of the Madison is about 1,000 feet below the top of the Tensleep and the formation is about 450 feet thick.

In the Plunkett area, SE¼ T. 1 S., R. 1 E., numerous shallow wells produced small quantities of oil from the Mowry Shale but are now inactive. A well drilled in 1964 nearby in SW¼SE¼ sec. 35, T. 1 S., R. 1 E., gauged 5.5 million cubic feet of gas per day from the Muddy. However, no oil or gas production is shown for the area in the 1973 Oil and Gas Conservation Commissioner's report. Some wells drilled in the area had oil and gas shows in the Tensleep and Park City Formations. Records do not show any tests of deeper formations in this area.

In the McGowan anticline area, secs. 24 and 25, T. 1 S., R. 1 E. and secs. 19, 30, 31, T. 1 S., R. 2 E., four unsuccessful test holes have been drilled. The deepest hole on the west end of the structure tested the Tensleep Sandstone. Two early holes (1925 and 1927) were drilled to the Sundance in the midsection of the structure, and a hole testing the Morrison Formation was drilled in 1969 near the plunging eastern axis. The Phosphoria and Tensleep remain untested in much of this area, however.

Coal

Almost the entire western one-third of the Wind River coal region is within the reservation, and four of the five principal basin coal fields lie wholly or partly within its boundaries (Figure 9). The largest field, the Powder River field,[1] lies outside the reservation. Both the Muddy Creek and Pilot Butte fields are located centrally in the reservation (see Figure 9), whereas the Hudson and the Alkali Butte fields are only partly within the reservation.

The Muddy Creek field in T. 5 and 6 N., R. 2 W. through 3 E. encompasses about 100 square miles of lenticular coals. Thickest coals are in the Shotgun district, along Muddy Creek (T. 6 N., R. 1 E.), where more than 17 feet of coal and 1.3 feet of partings occur in the Meeteetse Formation. The

[1] This field should not be confused with the Powder River field in the Powder River basin.

coal lenses out to about 6 inches within a few hundred feet downdip from the outcrop and then thickens, attaining a thickness of more than 9 feet in another hundred feet.

In the Dry Creek (Fivemile Creek) district of this field, T. 6 N., R. 2 W., the thickest coal is in the Mesaverde Formation where a nearly 9-foot-thick coal crops out along the northeast limb of a northwest trending syncline. The coal which dips from 70º SW to vertical, crops for nearly ¾ mile. However, its thickness is variable.

Small amounts of coal have been mined from several Mesaverde coalbeds in T. 5 N., R. 1 W. and 1 E. The coal is as much as 6 feet thick and dips 15 SE.

In the Sheep Creek and Dry Cottonwood districts of the Muddy Creek field (T. 6 N., R. 2 and 3 W.), maximum coal thickness is less than 5 feet.

Pilot Butte is a small isolated field in sec. 13, T. 3 N., R. 1 W. and contains less than 3 feet of coal in the basal Mesaverde Formation.

The Hudson field, in T. 33 and 34 N., R. 98 W. and T. 1 and 2 S., R. 2 E. contains three coal beds in a 45-foot interval of the Mesaverde Formation, which dips approximately 13 NE. Thickest measured coal section, 14 feet, is about 4 miles north of Hudson. Much of the coal in the field, however, is less than 5 feet thick. One persistent bed was traced for more than 3½ miles.

The Alkali Butte field, T. 2 S., R. 6 E., and T. 34 N., R. 94 and 95 W. contains two Mesaverde coal beds exposed intermittently on the northeast and west sides of a northwest-trending anticline. Beds around the flanks of the anticline dip 12º to 54º, but most dips are less than 30º. In the eastern end of the field, the lower coal bed is at least 12 feet thick. In the northeastern and western portions of the field, the upper bed reaches a maximum thickness of nearly 17 feet and maintains a minimum thickness of 10 feet for more than miles along the outcrop.

This apparently favorable area has not proven economical in past attempts at development because of a lack of a good water supply and good transportation.

Geologic controls.--Coal swamps were not extensive and the resulting coal beds are thin and lenticular. The thickest and most extensive beds of coal are in the Meeteetse (Keefer, 1965, p. A-62) and very minor amounts occur in the Shotgun Member of the Paleocene Fort Union Formation. Laramide folding affected all minable coals except the coal found in the Early Eocene Wind River Formation. Much of the coal is now thousands of feet below the surface.

Reserves.--If estimates of minable reserves are confined to beds with a maximum thickness of 5 feet, and if 50 percent of these beds are recoverable by underground mining methods, nearly 15 million short tons of coal is available on the reservation (Bolmer and Biggs, 1965).

Of the estimated 875 million tons of original coal reserves in the Wind River region, including measured, indicated, and inferred, about 73 million tons are within the reservation (Bolmer and Biggs, 1965), in beds thicker than 2½ feet at depths less than 3,000 feet (Table 6, Table 7, and Table 8).

Principal coal mining operations have been outside the reservation.

TABLE 6

Analyses of Coal Samples from Wind River Reservation*,**

Field and Mine	Location Sec	T	R	Air loss	Analysis, percent by weight as received: Mois-ture	Volatile matter	Fixed carbon	Ash	Sul-fur	Btu per lb.
Muddy Creek:										
Muddy Creek	20	6N	1E	10.4	15.7	28.6	47.6	8.0	0.4	9,920
Le Clair	30	6N	2E	14.2	21.3	29.0	37.7	12.0	0.3	8,150
Pilot Butte:										
Kinnear	13	3N	1W	10.4	14.8	34.0	42.6	8.6	0.9	10,190
Hudson										
Mitchell***	22	1S	2E	6.8	18.8	32.2	38.2	10.8	1.0	9,170
Indian***	2	2S	2E	8.4	21.1	31.4	41.7	5.8	0.5	9,460
Hickey	11	2S	2E	5.6	23.1	33.1	39.6	4.2	0.7	9,510
McKinley***	2	2S	2E	14.1	20.7	33.9	37.8	7.6	1.2	9,420
Alkali Butte:										
Shipton	5	2S	6E	22.4	34.1	30.4	29.3	6.2	.6	6,080

*Samples largely by Geological Survey; analyzed by Bureau of Mines

**Dobbin, C.E., and others (1931)

***Composite sample.

TABLE 7

Estimated Original Reserves of Subbituminous Coal in the Wind River Region*,** (million short tons)

	Measured	Indicated	Inferred	Total	Reserves on Reservation
Muddy Creek	-	42.50	-	42.50	42.50
Pilot Butte	-	0.36	-	0.36	0.36
Hudson	21.71	37.26	-	58.97	5.00
Alkali Butte	-	85.73	3.77	89.50	25.25
Tps. 33-34 N., R. 96 W.	-	208.11	299.36	507.47	-
Powder River	-	176.86	-	176.86	-
Total	21.71	550.82	303.13	875.66	73.11

*Beryhill, and others (1950).

**In beds more than 21½ ft. thick and under less than 3,000 ft. of cover

TABLE 8

Estimated Original Reserves of Subbituminous Coal by Township on Wing River Reservation*,**
(million short tons)

Field	Town-ship	Bed 2½-5 ft. thick	Beds 2-10 ft. thick	Township total
Muddy Creek	5N lW	-	1.38	1.38
Do	6N 2W	8.15	9.62	17.77
Do	6N lE	3.20	12.25	15.45
Do	6N 2E	5.16	-	5.16
Do	6N 3E	2.74	-	2.74
Field total		19.25	23.24	42.50
Pilot Butte	3N lW	0.36	-	0.36
Hudson	lS 2E	1.37	-	1.37
Do	2S 2E	3.63	-	3.63
Field total		5.00	-	5.00
Alkali Butte	1S 6E	6.19	-	6.19
Do	2S 6E	12.51	6.55	19.06
Field total		18.70	6.55	25.25
Reservation total		43.31	29.80	73.11

*Berryhill and others (1950).

**Under less than 3.000 ft. of cover.

Uranium

Although uranium has been mined in nearby areas, none has been produced from the reservation. Uranium-producing areas around the reservation are Copper Mountain, about 12 miles east; Gas hills, about 25 miles east-southeast; and Crooks Gap, about 40 miles southeast.

Geologic controls.--Wyoming Tertiary basins contain 42 percent of the nation's uranium ore based on a price of 10 dollars per pound (Patterson, 1970, p. 119). Love (1970, p. C129) lists the following possible sources for the solutions which formed the uranium deposits of the Granite Mountains area (Gas Hills, Shirley Basin, and Crooks Gap districts): 1) Precambrian granite of the Granite Mountains; 2) arkosic sandstones derived from the Precambrian granite of the Granite Mountains: 3) Precambrian vein deposits of hydrothermal origin (Guilinger, 1963); 4) Tertiary uraniferous tuff (Love, 1954; Pipiringos, 1961); 5) hydrothermal solutions (Melbye, 1957; Gabelman and Krusiewski, 1963).

Favored are sources 1), 2), and 4), either separately or in some combination. Harshman (1970, p. 227) favors a multiple source including the Precambrian granite in the cores of the flanking ranges and Tertiary tuffaceous rocks that were once more widespread in the eastern two-thirds of Wyoming. He also has shown that the altered arkose is not the source of the uranium, based on the presence in the altered sandstone of slightly more uranium and 10 to 20 times as much selenium as in the unaltered sandstone. Love (1970, p. 132) and Soister (1968, p. A48) favor Tertiary tuffaceous rocks as the source of the uranium in the Gas Hills and Crooks Gap districts.

Many geologists agree that whatever the source of the uranium bearing solutions, permeable clastic units, and particularly paleochannels, are favorable environments for uranium ore deposition. Furthermore, the formation of these deposits is related to the Tertiary tectonic and climatic history of Wyoming and the deposits seem to be limited to the Eocene Wind River Formation and its equivalents, at least in the vicinity of the reservation. In northeastern Wyoming on the west flank of the Black Hills uplift deposits are found in Cretaceous sandstones, but these deposits contain only a small fraction of the known uranium ore of Wyoming.

<u>Deposits.</u>--Bolmer and Biggs (1965) refer to radioactive anomalies along the northwestern boundary of the reservation in the Aycross Formation in T. 7 N., R. 5 W. Mining leases were granted a number of years ago in sec. 5, 7, and 8 of that township, but later were canceled. Remnants of the Aycross Formation are found between outcroppings of Precambrian granite on both sides of the North Fork of the Wind River on the reservation, largely in T. 7 and 8 N., R. 5 W.

<u>Potential resources.</u>--Potential resources of uranium are most likely to be found in coarse-grained arkosic channel sandstones of the Wind River Formation. However, some uranium has been found in Wyoming in nearly every geologic system from the Precambrian to the Holocene (Finnell and Parrish, 1958). The most significant occurrences of uranium in the Paleozoic rocks are in the phosphatic shales and dolomites of the Park City Formation (McKelvey and Carswell, 1956). They are extensive but are of very low grade. Permeable Cretaceous sandstones could be mineralized similar to those near the Black Hills, however, no uranium has been reported in these rocks in the Wind River basin.

Uranium prospecting is continuing in the area. One company, however, is canceling 105 leases of allotted lands in the northwest part of the reservation where tracts range in size from 20 to 640 acres. The same company recently obtained a prospecting permit for 55,172 acres of tribal lands in the south-central part of the reservation in T. 1 S., R. 1-3 E., T. 1 N., R. 1-3 E.; and T. 2 N., R. 1-3 E.

Non-Metallic Mineral Resources

Phosphate

Phosphate beds are found in the Park City Formation on the northeast slope of the Wind

River Range and at scattered locations in the Owl Creek Mountains (Figure 10).

The upper Park City is a resistant dolomite dipping 10 - 20 basinward that forms conspicuous dip slopes along the entire Wind River Range on the reservation. The phosphorite beds of the Park City are low grade, (13.8 to 22.9 percent P_20_5) and lie 40 to 55 feet above the base of the formation. Both the grade and the thickness of these beds decrease in a northwesterly direction. At best, marginal mining widths are on the reservation.

Phosphatic zones exposed on the flanks of the Owl Creek Mountains (Figure 10) appear to thin and to diminish in grade eastward. The Park City Formation in the Owl Creek Mountains has not been examined as extensively as in the Wind River Range (Bolmer and Biggs, 1965). This area warrants further study.

Because of the large reserves of better grade phosphate rock found in other western deposits, the development of deposits on the reservation should be deferred to the future.

Gypsum

Wyoming contains several high-grade gypsum deposits in 12 counties. Two deposits in Big Horn and Park Counties contain more than 80 million tons of gypsum, sufficient reserves to supply existing needs of nearby wallboard plants for a hundred years.

Factors favoring the potential growth of a gypsum industry on the reservation include continued market growth in the nearby northwestern states, numerous high-grade deposits on the reservation, good rail transportation links from the reservation to markets, minimal water requirements for development, and adequate local fuel supplies.

Gypsum beds on the reservation crop out on the northeast flank of the Wind River Range and on both flanks of the Owl Creek Mountains (Figure 11). Other outcrops are found associated with anticlinal structures in the relatively shallow sediments on the margin of the basin along the mountain front.

<u>Geologic controls</u>--The occurrences of gypsum on the reservation (Figure 11) are limited to the following stratigraphic units: the Dinwoody Formation, the Chugwater Group of Triassic age, and the gypsum Spring Formation of Jurassic age. The thickest and most, extensive beds of gypsum occur in the Gypsum Spring Formation.

Gypsum beds are generally considered to be minable if they contain at least 85 percent gypsum. A massive bed in the Gypsum Springs Formation on the reservation contains about 96 percent gypsum, (Bolmer and Biggs, 1965).

<u>Deposits.</u>--Gypsum deposits on the reservation include the following:

<u>Fremont County</u>

- NE¼ sec. 24, T. 2 S., R. 1 E., to NW¼ sec. 19, T. 2 S.. R. 2 E. -- Lander area
- SW¼NW¼ sec. 5, T. 2 S., R. 1 W. -- Mill Creek (south side)
- SW¼ sec. 15, T. 1 N., R. 1 W. -- Sage Creek anticline (NE flank)
- T. 1 and 2 S., R. 1 and 2 W. -- Wind River Mountain Front

T. 1 and 2 N., R. 3 W. -- Wind River Mountain Front (40 ft. thick from Soral to Trout Creeks, 50 ft. on Pevah Creek, 70 ft. from South to North Forks Sage Creek, and 125 ft. on Bull Lake Creek)

SW¼ sec. 2 to NW¼ sec. 11, T. 6 N., R. 2 E. -- East Fork of Sheep Creek

T. 6 N., R. 3 and 4 E. -- Sears Ranch (35-40 ft.)

Sec. 22, 23, 25, 26, and 36, T. 6 N., R. 2 W., -- Maverick Springs anticline

Sec. 6, T. 6 N., R. 3 W. -- Red Creek

Sec. 1, T. 6 N., R. 4 W. -- Red Creek

Sec. 36, T. 7 N., R. 4 W. -- Red Creek

Sec. 6 and 7, T. 6 N., R. 2 W. -- Circle Ridge anticline (95-120 ft. thick)

Sec. 1, T. 6 N., R. 3 W. -- Circle Ridge anticline (95-120 ft. thick)

Sec. 3, T. 7 N., R. 2 W. -- Circle Ridge anticline (95-120 ft. thick)

Sec. 36, T. 7 N., R. 3 W. -- Circle Ridge anticline (95-120 ft. thick)

Sec. 29 and 32, T. 7 N., R. 1 E. -- Phlox Mountain area

Sec. 19, 20, and 30, T. 7 N., R. 1 W. -- Antelope Ridge area

T. 7 N., R. 2 W. -- Muddy Creek-Red (Antelope) Basin area

Hot Springs County

T. 7 N., R. 3 and 4 E. -- Red Creek Canyon valley (30-40 ft. thick)

Sec. 27, T. 8 N., R. 3 E. -- Mud Creek

T. 8 N., R. 1 E. -- Red Creek (30 - 40 ft. thick)

The total gypsum reserves of the reservation are very large (Bolmer and Biggs, 1965). Strippable reserves on the Maverick Springs anticline in secs. 22, 23, and 26, T. 6 N., R. 2 W. are 14.3 million tons. This deposit has a thickness of 10 to 60 feet. Stripping ratio is 0.13 to 1, with 1.8 million tons of stripping required.

Potential.--At present the gypsum of the reservation is only a potential resource because it is too far from markets. Deposits that are served by nearby railroads, such as those near Lander, should have the best potential for development.

Bentonite

Wyoming is the nation's leading source of bentonite. In the Wind River basin, the most abundant source is in the Mowry Shale; lesser amounts occur in the underlying Thermopolis Shale and the overlying Frontier Formation. Bentonite exposures within the reservation are found on flanks of the Owl Creek Mountains and the Wind River Range as well as along the mountain fronts around anticlines in the Wind River basin (Figure 12).

In other parts of Wyoming, nearly horizontal deposits of high- quality bentonite only 2½ feet thick with little or no overburden have been profitably mined. Many deposits on the reservation are more than 5 feet thick.

Bentonite quality usually decreases rapidly with depth of burial because deeply buried deposits have limited swelling properties. Quality often is below commercial grade in deposits having more than 15 feet of overburden (Bolmer and Biggs, 1965).

Bentonite processing plants require very little water, but they do require fuel for drying and grinding. Mine-run bentonite may contain as much as 35 percent moisture.

Deposits.--Many bentonite deposits are within or near the reservation (Bolmer and Biggs, 1965), in the following area.

Fremont County

Secs. 11 and 14, T. 6 N., R. 2 E. Nine beds, ranging in thickness from 1 to 6 ft., total 24 ft. of bentonite in 560 ft. of Mowry Shale.

T. 6 N., R. 2 W. Two 5-ft. beds of bentonite in Mowry Shale crop out around Maverick Springs anticline.

T. 8 N., R. 6 W. A 5- to 10-ft. thick bentonite deposit 1 mile northeast of Duncan Post Office

Secs. 32 and 33, T. 7 N., R. 2 W. Bentonite beds in Mowry shale along Blue Draw north of Circle Ridge and Maverick Spring anticlines.

Hot Springs County

Bentonite crops out in the Frontier and other formations along the north flank of the Owl Creek Mountains.

Potential.--Extensive bentonite deposits are on the reservation, but no commercial deposits have been delineated. Systematic sampling might reveal commercial deposits.

Sandstone

Widespread deposits of various types of sandstone are available on the reservation. Bolmer and Biggs (1965) list the following sources:

Flathead Sandstone -- Thin-bedded sandstone and quartzite.

Tensleep Sandstone -- Hard, massive quartz sandstone.

Chugwater Group -- Numerous, hard, limy, fine-grained, thin-bedded.

Nugget Sandstone -- Massive to thick-bedded. Has been used locally for building stone.

Muddy Sandstone -- Hard, medium to coarse-grained, shale partings. Used for riprap, foundations, and as building stone.

Frontier Formation -- Fine- to medium-grained. Up to 150 ft. thick. Extensively used locally for building stone.

Mesaverde Formation -- Sandstones ranging from hard, thin to soft and massive.

After completion of tribal buildings a few years ago, the tribal council did not grant new permits to mine stone.

Sand and gravel

Abundant supplies of sand and gravel are on the reservation. Numerous sand and gravel pits have been operated for local use. Gradually expanding markets are anticipated owing principally to increased population and industrialization. No shortage is anticipated locally or throughout most of the state in the immediate future. Tribal records reveal that 46,561 cubic yards were produced in fiscal year 1974, and tribal and allotted revenues totaled $16,347.

In 1973, eight active pits were in Fremont County and two in Hot Springs County. In the past, pits were operated to meet local, short-term needs, such as for highway construction. After a project was completed in one area, the sand and gravel pit was abandoned.

Large deposits that appear adequate for foreseeable local needs are found along the Wind and Popo Agie Rivers. Equally large deposits are in other parts of the reservation.

Asbestos

Asbestos occurrences are reported in sec . 5 , T. 7 N., R . 5 W., in sec. 32, T. 8 N., R. 5 W., and in sec. 7, T. 42 N., R. 104 W., at the west end of the Owl Creek Mountains. Amphibole asbestos fills fractures and cleavage planes in a thick diabase dike; fibers are reportedly weedy and brittle.

Other occurrences in Fremont County have been found south of the reservation, but only small quantities have been produced. Asbestos production on the reservation does not appear likely.

Metallic Mineral Resources

Gold

Placer deposits.--Placer gold occurs widely within the reservation, but is generally too fine for commercial recovery. Unsuccessful attempts have been made to mine the deposits for the past century.

Drainages were systematically examined in 1913 for gold, and the best results were obtained along the Wind River near Neble, about 7 miles downstream from Riverton in T. 1 and 2 N., R. 2 E. The gravels, reportedly averaging about 22 feet to bedrock, yielded about 49 cents in gold per cubic yard (gold was $20.00 an ounce). Dredging operations west of Riverton in 1910, averaged $1.33 to $1.40 gold per cubic yard (Bolmer and Biggs, 1965)

Gold in the placer deposits probably originated from lode deposits in the Owl Creek Mountains and Wind River Range.

Lode deposits.--In the Boysen area, near the entrance to Wind River canyon in T. 5 and 6 N., R. 6 E., Precambrian rocks contain several narrow quartz veins. Mining development was not sustained following the early-day exploration.

On the St. Lawrence Creek in the Wind River Mountains, T. 1 N., R. 3 and 4 W., gold-bearing quartz stringers up to 4 feet wide are in Precambrian granite and schists. Minor amounts of gold and silver are present in copper prospects on Willow Creek in the Owl Creek Mountains, T. 6 N., R. 3 E. Quartz veins associated with diorite dikes in Precambrian granite and schists contain copper carbonates and minor amounts of copper sulfides, gold, and silver (Bolmer and Biggs, 1965).

Geologic controls.-- Gold-quartz lode deposits are in hydrothermal veins of quartz that either replace wallrock or fill fractures. These veins are in the Precambrian granites and schists of the Wind River Range and Owl Creek Mountains. There is no recorded production from the gold-quartz veins on the reservation. Some of these veins were obviously the source of the placer gold in sand and gravel along the Wind, Little Wind and Popo Agie Rivers, (Bolmer and Biggs, 1965). p. 96). A more likely source for much of the gold is the Harebell Formation (Upper Cretaceous) and the Pinyon Conglomerate (Upper Cretaceous and Paleocene) of the Jackson Hole region to the west of the reservation (Simons and Prinz, 1973, p. 272).

Although at present the auriferous quartzite roundstone conglomerates are separated from the Wind River basin by the continental divide, geologic evidence from the Wind River basin suggests that this was not always the case. Rounded quartzite pebbles and cobbles (termed "roundstones") typical of Pinyon and Harebell conglomerates are found in Wind River Formation channel deposits in the western Wind River basin. Paleocurrent studies indicate that the source area for the Eocene Wind River Formation was not only the ranges flanking the Wind River basin but also an indeterminate source to the west which must have included the gold-bearing Cretaceous and Paleocene conglomerates of the Jackson Hole region.

A well indurated quartzite roundstone pebble, cobble, and boulder conglomerate crops out on the east side of Bald Mountain five miles west of Dubois, Wyoming at an elevation of 8900 feet in the SE¼ sec. 8, T. 41 N., R. 107 W. Imbrication measurements indicate southward transport. Lindsey's (1972) map of mean maximum quartzite roundstone lengths shows an eastward decrease in maximum quartzite roundstone lengths from 15 inches to 12 inches in a distance of about 18 miles. Extrapolating from these data the Bald Mountain locality 15 miles east would be expected to have a mean maximum of about 9 inches, which it does. Lindsey (1972, p. B37 and p. B39) also shows a southerly stream transport direction in the outcrops of Pinyon Conglomerate nearest the Bald Mountain locality. This indicates that the Jackson Hole conglomerates may have extended into the northwestern Wind River Basin. Part of the Wind River Formation was derived from gold-bearing conglomerates of the Jackson Hole area but enrichment from local sources of gold may have occurred, also.

Potential resources.-- The placer deposits of the reservation might become worthy of study if the price of gold reaches 200 dollars an ounce. In addition to recent placers, identification of the Pinyon as a source for some channel conglomerates in the Wind River Formation suggests that fossil placers may exist.

Iron

The Precambrian rocks of the Wind River Range and the Owl Creek Mountains contain lenses of iron-formation. Iron-formation occurs in the southern part of the Wind River Range near Atlantic City and also a few miles west of the reservation in the Wind River range on the west side of Downs Mountain (at the head of Dinwoody Creek). The Downs Mountain area has iron-formation lenses in an area about 3600 feet by 2500 feet and 300 feet thick but, although the iron-formation contains 25 percent iron, it makes up only 50 to 60 percent of the exposure (Worl, 1968, p. 14). The deposit is too small and too far from roads to be economic. An aeromagnetic survey might find other more accessible bodies. The Precambrian rocks of the Owl Creek Mountain include iron-formation about 10 miles east of the reservation.

Copper

Small amounts of copper associated with gold have been found on Willow Creek.

"West of the Wind River, near the crest of the Owl Creek Range, quartz veins containing copper minerals are found associated with Precambrian dikes and schists. Only very minor amounts of copper minerals were found." (Cameron Eng., 1969 a).

LEGAL CONSIDERATIONS

Mineral Ownership

Mineral ownership, including oil and gas, is as follows: On tribal lands mineral rights are held by the two tribes; on allotted lands minerals are held by the allottees or their heirs; and on fee- patent lands they may be held by the fee-patent holder, retained by the tribe, or retained by the government. An example of fee land mineral rights not retained by the government are the early homestead entries. However, mineral rights on most of the homestead entries are retained by the government.

Certain ceded Indian lands have been withdrawn at various times for the Riverton Reclamation project. The largest withdrawn area lies in the vicinity of Ocean Lake; other withdrawn areas are: Bull Lake Reservoir, Dinwoody Lake Reservoir, Wind River Diversion Dam, and part of the lands at Boysen Reservoir.

Regulations governing the Wind River Irrigation project are contained in the CFR Title 25, 1974.

Roadless Area

A roadless area on Indian lands is defined as containing at least 100,000 acres, with no provision for the passage of motorized transportation. The Wind River roadless area encompasses approximately 180,387 acres in the southwest corner of the reservation (Figure 1), and is the only existing roadless area on an Indian reservation.

Prospecting Permits

Prospecting permits on tribal lands for specific minerals may be issued by the reservation superintendent with the approval of the tribal council. The permits define the mineral sought, designate the area, and stipulate the period of time. A fee of $10.00 is charged for the permit, and a performance bond is required to insure compliance with applicable regulations. A prospecting permit ordinarily does not grant the permit holder preferential status in the granting of a lease.

Mineral Leasing

Regulations governing the leasing of tribal and allotted Indian lands for mining (including oil and gas) also are in CFR Title 25, 1974. A mineral lease application for tribal lands is made to the Joint Business Council of the Arapahoe and Shoshone tribes, whereas a mineral lease application on allotted lands is made to the reservation superintendent. Lease sales must be published 30 days before the sale, unless a shorter period of time is authorized by the Commissioner of Indian Affairs. The sales notice must specify the tract(s) offered.

Leases are usually granted to the highest bidder offering a bonus above the stipulated rent and royalty. However, mineral leases on tribal and allotted land are granted subject to approval of the Secretary of the Interior. The Secretary may reject bids and also, with the consent of the tribal council, may privately negotiate a lease.

A single lease normally is limited to 2,560 acres, but under some circumstances a coal lease may not be so limited. Coal leased lands shall not exceed a length of 1 mile along the outcrop.

Aggregate oil and gas lease holdings by an individual or company are limited to no more than 10,240 acres, and leases must be located in the same general area. Lode deposit leases are comprised of standard size mining claims of 600 feet width and 1,500 feet length, that conform to Federal mining claim laws.

Leases for mineral deposits are granted for a term not to exceed 10 years. Lease life may be extended indefinitely when minerals are being produced in commercial quantities. Leases, or interests in leases, may be assigned or transferred, provided that the assignee is qualified to hold the lease, provides a surety bond, and has the approval of the Secretary of the Interior.

A minimum advance rental of $1.25 per acre per annum is required for oil and gas leases. The royalty is at least 16 ⅔ percent of all hydrocarbons produced and saved.

For other minerals, unless specifically authorized otherwise standard leases stipulate a minimum annual expenditure of $10 per acre for development plus an annual advance rental of not less than $1 per acre. A production royalty is also assessed. For coal, the royalty is 17½ cents per short ton of mine-run production including slack. For most other minerals, the production royalty is 10 percent at the nearest shipping point. Special permits are granted for mining sand, gravel, and pumice. Fixed-fee permits are issued for quantities up to 200 cubic yards; for long-term permits charges are $10 for the permit and a royalty of 50 cents per cubic yard.

If a discovery results in commercial recovery of minerals, advance rentals received by the tribe are credited to production royalties for that year.

A surety bond is required with each lease or prospecting permit. The surety bond is $1,000 for leases or permits on 80 acres or less, $1,500 for 80 to 120 acres, $2,000 for 120 to 160 acres, and $500 for each additional 40 acres. In lieu of the above bonds, one bond of $75,000 provides national coverage, or a $15,000 bond provides coverage within a single state.

RECOMMENDATIONS FOR FURTHER WORK

Stratigraphic traps in Cretaceous rocks, and secondarily in the pre-Cretaceous rocks, present the highest potential for the discovery of additional oil and gas. The traps could be located by detailed surface and subsurface studies of stratigraphy and depositional environments.

A reconnaissance geologic study of the bentonite -bearing Thermopolis, Mowry, and Frontier Formations would provide data with which to more accurately assess the value of this potential bentonite resource. Aeromagnetic surveys of the Precambrian core areas of the Wind River Range and Owl Creek Mountains might find iron-formations similar to those found east of the reservation in the Owl Creek Mountains and south and west of the reservation in the Wind River Range.

A known source of gold exists in the Harebell Formation and Pinyon Conglomerate of the Jackson Hole area. The Pinyon Conglomerate was deposited in the western Wind River basin and clasts from the gold- bearing conglomerates of these two areas were transported eastward to form channel conglomerates in the Eocene Wind River Formation. Perhaps there are placer deposits in recent alluvial deposits, particularly in the western part of the reservation.

Channel sandstones in the Wind River Formation are favorable environments for development of uranium ore. A paleocurrent study of the Wind River Formation could delineate the approximate location of the Eocene Wind River and its channel sandstones.

REFERENCES

Andrews, D. A., 1944, Geologic and structure contour map of the Maverick Springs area, Fremont County, Wyoming: U. S. Geol, Survey Oil and Gas Inv. Map OM-13.

Barrus, R. B., 1968, The bedrock geology of southeastern Alpine Lake quadrangle, Wind River Mountains, Wyoming: Washington Univ. Thesis, 45 p.

Barton, W. R. 1963, Gypsum: U. S. Bur. Mines Yearbook, v. 1, p. 583-594.

Bates, R. L., 1960, Geology of the Industrial rocks and minerals: Harper and Row, New York, 441 p.

Beckwith, R. H., 1939, Asbestos and chromite deposits of Wyoming: Econ. Geology, v. 34, no. 7, p. 812-843.

Berryhill, H. L., Brown, D. M., Burns, R. N., and Combo, J. X., 1951, coal resources map of Wyoming, U. S. Geol. Survey Coal Inv. Map, C-6, 1:500,000

Berryhill, H. L., Jr., Brown, D. M., and Taylor, D. A., 1950, Coal resources of Wyoming: U. S. Geol. Survey Circ. 81, 78 p.

Biggs, P., and Espach, R. H., 1960, Petroleum and natural gas fields in Wyoming: U. S. Bur. Mines Bull. 582, 538 p.

Blackstone, D. L., Jr., 1948, The structural pattern of the Wind River basin, Wyoming: Wyoming Geol. Assoc, Guide Book, p. 69-78.

Bolmer, R. L., and Biggs, P., 1965, Mineral resources and their potential on Indian lands, Wind River reservation, Fremont and Hot Springs Counties, Wyoming: U. S. Bur. Mines Prelim. Rept. 159, 103 p.

Bowles, O., 1956, Limestone and dolomite: U. S. Bur. Mines Inf. Circ. 7738, 29 p.

Brobst, D. A., and Pratt, W. P., 1973, Introduction to United States mineral resources, Rl-8 in Brobst, D. A., and Pratt, W. P., eds., United States Mineral Resources: U. S. Geol. Survey Prof. Paper 820, 722 p.

Cameron Engineers, 1969a, Coal forecast: Review and forecast, Wyoming Mineral Industries, Book I, Summary, Book II, Wind River coal, pp. 256-257.

___,1969b, Distribution of mineral ownership: Review and Forecast, Wyoming Mineral Industries, Book II, Mineral Fuels.

___, 1969c, Non-fuel minerals: Review and Forecast, Wyoming Mineral Industries, Book III. CFR Title 25, 1974, Indians, Chapter, Bureau of Indian Affairs, U. S. Dept. of Interior.

Childers, M. O., 1974, Uranium occurrences in upper Cretaceous and Tertiary strata of Wyoming and northern Colorado: The Mountain Geologist, v. 11, No. 4, p. 131-147.

Coffman, J. S., and Service, A. L., 1967, An evaluation of the western phosphate industry and its resources (in five parts): Pt. 4, U. S. Bur. Mines Rept. Inv. 6934., 158 p.

Collier, A. J., 1920, Anticlines near Maverick Springs, Fremont County, Wyoming: U. S. Geol. Survey Bull. 711, 149-166.

Condit, D. D., 1924, Phosphate deposits in the Wind River Mountains, near Lander, Wyo.: U. S. Geol. Survey Bull. 764, 39 p.

Counselman, Betty Jo, 1973: Annual report on Indian Lands, as of June 30, 1973: U. S. Bur. Indian Affairs, 47 p.

Dempsey, W. J., Stuart, J. D. and others, 1963, Aeromagnetic map of the northeastern part of the Wind River Indian reservation, Wyoming: U. S. Geol. Survey Geophysical Inv. Map GP-400, scale 1:62,500.

___, 1962, Aeromagnetic map of south-central (Fremont County), Wyoming: U. S. Geol. Survey Geophysical Inv. Map, GP-393.

Dobbins, C. E. 1931, Analyses of Wyoming coals: U. S. Bur. Mines Tech. Paper 484, p. 1-9.

Ebens, R. J., and Smithson, S. B., 1966, Petrography of Precambrian rocks from a 3.05 kilometer-deep borehole, Wind River Mountains, Wyoming: Contr. to Geology, v. 5, p. 31-38.

Ellerby, R. S., 1962, Geology of the Dry Creek-Willow Creek area, Fremont County, Wyoming: Wyoming Univ. Thesis.

Fenneman, N. M., 1931, Physiography of western United States: McGraw-Hill, 534 p.

Finnell, T. L., and Parrish, I. S., 1958, Uranium deposits and principal ore-bearing formations of the central Cordilleran foreland region: U. S. Geol. Survey Mineral Inv. Map MF-120.

Gabelman, J. W., and Krusiewski, S. V., 1963, The application of hydrothermal zoning to Wyoming uranium deposits: Am. Inst. Mining, Metall., and Petroleum Engineers: 8th Ann. Uranium and Minerals Symposium, p. 11-41.

Glass, G. B., May 1972, Review of Wyoming coal fields, 1971: Wyoming Geol. Survey, 32 p.

Granger, H. C., McKay, E. J., Mattick, R. E., Patten, L. L. and McIlroy, P., 1971, Studies related to wilderness-primitive areas, Glacier, Wyoming: U. S. Geol. Survey Bull. 1319-F, 113 p.

Guilinger, R. R., 1963, Source of uranium in the Gas Hills area, Wyoming: Econ. Geology, v. 58, no. 2, p. 285-286.

Harrer, C. M., 1955, Gypsum within the Missouri Basin Region of Wyoming and Colorado: U. S. Bur. Mines Prelim. Rept. 103, 66 p.

Harshman, E. N., 1970, Uranium ore rolls in the United States, in Uranium Exploration Geology: Vienna, Austria, Internat. Atomic Energy Agency, p. 219-230.

Havard, J. F., 1960, Gypsum--Industrial minerals and rocks: Am. Inst. Mining, Metall., and Petroleum Engineers, p. 471-486.

Holladay, C. O., 1959, Geology of northwestern Blue Holes quadrangle, Fremont County, Wyoming: Miami Univ. Thesis.

Holmes., R. F., Jr., 1959, The geology of East Fork-Wind River Junction area, Blue Holes quadrangle, Fremont County, Wyoming: Miami Univ. Thesis.

Horn, G. H., 1963, Geology of the east Thermopolis area, Hot Springs, and Washakie Counties, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Map OM-213.

Hunt, J. M., and Foreman, J. P., 1957, Relation of crude oil composition to stratigraphy in the Wind River basin: Wyo. Geol. Assoc. Guidebook, southeast Wind River basin, p. 105-118.

Hutchinson, V. V., 1972, Selected list of Bureau of Mines publications on petroleum and natural gas, 1961-1970, U. S. Bur. Mines Inf. Circ. 8534, 163 p. suppl. to U. S. Bur. Mines Inf. Circ. 8240.

Keefer, W. R., 1957, Geology of the Du Noir area, Fremont County, Wyoming: U. S. Geol. Survey Prof. Paper 294-E, p. 155-221.

___, 1961, Waltman Shale and Shotgun Members of the Fort Union Formation (Paleocene) in Wind River basin, Wyoming: Am. Assoc. Petroleum Geologists Bull. v. 45, no. 8, p. 1310-1323.

___, 1965, Stratigraphy and geologic history of the Uppermost Cretaceous, Paleocene, and Lower Eocene rocks in the Wind River Basin, Wyoming: U. S. Geol. Survey Prof. Paper 495-A, 77 p.

___, 1969, Geology of petroleum in Wind River basin, central Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 9, p. 1839-1865.

___, 1970, Structural geology of the Wind River basin, Wyoming: U. S. Geol. Survey Prof. Paper 495-D, p. Dl-D35.

Keefer, W. R., and Rich, E. I., 1957, Stratigraphy of the Cody shale and younger Cretaceous and Paleocene rocks in the western and southern parts of the Wind River basin, Wyoming: in Wyoming Geol. Assoc. Guidebook 12th Ann. Field Conf. Southwest Wind River Basin 1957, p. 71-78.

Keefer, W. R., and Troyer, M. L., 1964, Geology of the Shotgun Butte area, Fremont County, Wyoming: U. S. Geol. Survey Bull. 1157, 123 p.

Keefer, W. R., and Van Lieu, J. A., 1966, Paleozoic formations in the Wind River basin, Wyoming: U. S. Geol. Survey Prof. Paper 495-B, p. Bl-B60.

Ketner, K. B., Keefer, W. R., Fisher, F. S., and Smith, D. L., I J. S. Geol. Survey, and Raabe, R. G., U. S. Bur. of Mines, 1966, Mineral resources of the stratified primitive area, Wyoming: U. S. Geol. Survey Bull. 1230-E, 56 p.

King, R. H., 1947, Phosphate deposits near Lander, Wyo.: Wyoming Geol. Survey Bull. 39, 84 p.

Kirkwood, W. C., 1957, Sage Creek and North Sage Creek domes: Wyoming Geol. Assoc. Guidebook, southwest Wind River basin, p. 124-131.

Kisling, D. C., 1962, Geology of the Antelope Ridge area, Fremont and Hot Springs Counties, Wyoming: Wyoming Univ. Thesis.

Lamb, R. C., Jr., 1954, A geology of the Dinwoody Creek area, Fremont County, Wyoming: Kansas Univ., 78 p.

Lane, R. W., 1957, Winkleman Dome oil field: Wyoming Geol. Assoc. Guidebook, Southwest Wind River basin, p. 119-123.

Larson, L. P., 1960, Gypsum in Mineral Facts and Problems: U. S. Bur. Mines Bull. 585, p. 367-375.

Lindsey, D. A., 1972, Sedimentary petrology and paleocurrents of the Harebell Formation, Pinyon conglomerate, and associated coarse clastic deposits, northwestern Wyoming: U. S. Geol. Survey Prof. Paper 734-B, 68 p.

Love, J. D., 1934, The geology of the west end of the Owl Creek Mountains: Wyoming Geol. Survey Bull. 24, 34 p.

___, 1939, Geology along the southern margin of the Absaroka Range, Wyoming: Geol. Soc. America Spec. Paper 20, 134 p.

___, 1945, Preliminary report on uranium in the Gas Hills area, Fremont County, Wyoming: U. S Geol. Survey Circ. 352, 11 p.

___, 1961, Definition of Green River, Great Divide and Washakie Basins, southwestern Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 45, no. 10, p. 1749-1755.

___, 1970, Cenozoic geology of the Granite Mountains area, central Wyoming: U. S. Geol. Survey Prof. Paper 495-C, 154 p.

Love, J. D., Johnson, C. O., Nace, H. L., Sharkey, H. H. R., Thompson, R. M.,

Tourtelot, H. A., and Zapp, A. D., 1945, Stratigraphic sections and thickness maps of Triassic rocks in central Wyoming: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 17.

Love, J. D., Tourtelot, H. A., Johnson, C. O., Sharkey, H. H. R., Thompson, R. M., and Zapp, A. D., 1945, Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart H.

Majors, F. T., 1946, Exploration of the Brutch sulfur deposits, Hot Springs County, Wyoming: U. S. Bur. Mines Rept. Inv. 3964, 15 p.

McGreevey, L. J., Hodson, W. G.,and Rucker, S. J., IV, 1969, Groundwater resources of the Wind River Indian Reservation, Wyoming: U. S. Geol. Survey Water-Supply Paper 1576-I, 145 p.

McKelvey, V. E., and Carswell, L. D., 1956, Uranium in the Phosphoria Formation (U.S.) in United Nations, Geology of uranium and thorium: Internat. Conf. Peaceful Uses Atomic Energy, Geneva Aug. 1955, Proc., v. 6, p. 503-506.

McKelvey, V. E., Williams, J. S., Sheldon, R. P., Cressman, E. R., Cheney, T. M. and Swanson, R. W., 1956, Summary description of Phosphoria, Park City and Shedhorn Formations in western phosphate field: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 12, p. 2826-2863.

Meeves, H. C., 1966, Nonpegmatic beryllium occurrences in Arizona, Colorado, New Mexico, Utah, and four adjacent states: U. S. Bur. Mines Rept. Inv. 6828, 68 p.

___ , 1966, Reconnaissance of beryllium-bearing pegmatite deposits in six western states: Arizona, Colorado, New Mexico, South Dakota, Utah, and Wyoming: ll. S. Bur. Mines Inf. Circ. 8298, 17 p.

Melbye, C. E., 1957, Structural control of Crooks Gap gives clues for Wyoming prospectors: Mining World, v. 19, no. 12, p. 45-57, 108-109.

Milton, A. A., May 1942, Geology of the Circle Ridge-Spring Mountain area, Owl Creek Mountains, Wyoming: Iowa Univ. Thesis.

Moyer, F. T., Gypsum and anhydrite: U. S. Bur. Mines Inf. Circ. 7049, 45 p.

Murphy, J. F., and Richmond, G M., 1965, Geologic map of the Bull Lake west quadrangle, Fremont County, Wyoming: U. S. Geol. Survey, Geol. quadrangle map G-432, 1:24,000. Osterwald, F. W., and others, 1966, Mineral resources of Wyoming / revised_/: Wyoming Geol. Survey Bull. 50, 240 p. Patterson, J. A., 1970, Character of the United States uranium resources, in Uranium exploration geology: Vienna, Austria, Internat. Atomic Energy Agency, p. 117-128.

Pearson, R. C., Kiilsgaard, T. H., Patten L. L., and Mattick, R. E., 1971, Mineral resources of the Popo Agie primitive area, Fremont and Sublette Counties, Wyoming: U. S. Geol. Survey Bull. 1353-B, 55 p.

Peterson, E. C., 1966, Titanium resources of the United States: U. S. Bur. Mines Inf. Circ. 8290, 48 p.

Peterson, J. A., 1972, Jurassic system in Mallory, W. W. (ed.) Geologic Atlas of the Rocky Mountain Region: Rocky Mountain Assoc. of Geologists, Denver, 331 p.

Pipiringos, G. N., 1961, Uranium-bearing coal in the central part of the Great Divide Basin: U. S. Geol. Survey Bull. 1099-A, 104 p.

Richmond, G. M., and Murphy, J. F., 1965, Geologic map of the Bull Lake East quadrangle, Fremont County, Wyoming: U. S. Geol. Survey, Geol. Quad. Map GQ-431.

Root, F. K., 1972, Minerals and rocks of Wyoming: Wyoming Geol. Survey Bull. 56, 54 p.

Shafer, A. W., 1973, Annual report of the State Inspector of Mines of Wyoming: Office of the State Inspector of Mines, Cheyenne, Wyoming.

Sharkey, H. H. R., and Thompson, R. M., 1957, The habitat of oil in the Wind River basin, Wyoming: Wyoming Geol. Assoc. Guidebook, Southwest Wind River basin, pp. 97-104.

Sheldon, R. P., 1957, Physical stratigraphy of the Phosphoria Formation in northwestern Wyoming: U. S. Geol. Survey Bull. 1042-E, p. 103-185.

___, 1964, Paleolatitudinal and paleogeographic distribution of phosphorite; U. S. Geol. Survey Prof. Paper 501-C, p. C106-C113.

Simons, F. S., and Prinz, W. C., 1973, Gold, p. 263-275 in Brobst, D. A., and Pratt, W. P., eds., U. S. Mineral Resources: U. S. Geol. Survey Proft Paper 820, 722 p.

Smith, J. B., and others, 1972, Strippable coal reserves of Wyoming, location, tonnage, and characteristics: U. S. Bur. Mines Inf. Circ. 8538, p. 48.

Soister, P. E., 1968, Stratigraphy of the Wind River Formation in southcentral Wind River basin, Wyoming: U. S. Geol. Survey Prof. Paper 594-A, 50 p.

Smithson, S. B., and Ebens, R. J., 1971, Interpretation of data from a 3.05 kilometer borehole in Precambrian crystalline rocks, Wind River mountains, Wyoming: Jour. Geophys. Research, vol. 76, no. 29, p. 7079-7087.

Stauffer, J. E., Petroleum potential of Big Horn Basin and Wind River Basin - Casper Arch area, Wyoming, and Crazy Mountain Basin Bull Mountains basin area, Montana: Am. Assoc. Petroleum Geologists Mem. 15, vol. I, p. 613-655.

Thomas, H. D., 1951, Wyoming petroleum possibilities enhanced by variety of traps: Wyoming Geol. Survey, Reprint, World Oil, v. 132, no. 6.

Thompson, R. M., 1958, Geology and oil and gas possibilities of the Wind River basin, Wyoming, in Weeks, L. G., eds., Habitat of oil a symposium, Am. Assoc. Petroleum Geologists, p. 307-327.

Thompson, R. M., Love, J. D., and Tourtelot, H. A., 1949, Stratigraphic sections of pre-Cody Upper Cretaceous rocks in central Wyoming: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 36.

Thompson, R. M., Troyer, M. L., White, V. L., and Pipiringos, G. N., 1950, Geology of the Lander area, central Wyoming: U. S. Geol. Survey Oil and gas Inv. Map OM-112.

Tourtelot, H. A., Thompson, R. M., 1948, Geology of the Boylen area, central Wyoming: U. S. Geol. Survey Oil and Gas Inv. Map OM-91.

Troyer, M. L., 1951, Geology of the Lander (Hudson) and Plunkett anticlines and vicinity, Fremont County, Wyoming: Wyoming Thesis.

Turner, O. D., 1959, Resources of Wyoming and their relation to industrial development, Wyoming Univ., Laramie, Wyoming.

U. S. Atomic Energy Commission (prepared by Texas Instruments Incorporated), May 7, 1975, Airborne Geophysical Survey, Wind River basin area, Wyoming: Open file Rept. available for consultation at the Grand Junction, Colo. office of ERDA (successor to the Atomic Energy Comm.)

U. S. Bureau of Mines, 1965, Mercury potential of the United States: U. S. Bur. Mines Inf. Circ. 8252, 376 p.

U. S. Government, 1974, Code of Federal Regulations, Title 25 -- Indians: Bur. of Indian Affairs, U. S. Dept. of Interior, pt. 163.1

Whitcomb, H. A., and Lowry, M. E., 1968, Ground-water resources and geology of the Wind River basin area, central Wyoming: U. S. Geol. Survey Hydrologic Inv. Atlas HA-270.

Williams, M. D., and Sharkey, H. H. R., 1956, Geology of the Barges area, Fremont County, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Map OM-56.

Williamson, D. R., 1963, Colorado gypsum and anhydrite: Colorado School of Mines Mineral Industries Bull., v. 2, 20 p.

Withington, C. F., 1962, Gypsum and anhydrite in the United States: U. S. Geol. Survey Mineral Inv. Res. Map MR 33.

Withington, C. F., and Jaster, M. C., 1960, Selected annotated bibliography of gypsum and anhydrite in the United States and Puerto Rico: U. S. Geol. Survey Bull. 1105, 126 p.

Worl, R. G., 1968, Taconite in the Wind River Mountains, Sublette County, Wyoming: Wyoming Geol. Survey Prelim. Rept. No. 10, 15 p.

Wyoming, State of, 1963, Overlay maps: Wyoming Natural Resource Board. ___, 1967, Wyoming's natural resources and their management: Wyoming

Game and Fish Dept.

Yenne, K. A., and Pipiringos, G. N., 1954, Stratigraphic sections of Cody shale and younger Cretaceous and Paleocene rocks in the Wind River basin, Fremont County, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Chart OC-49.

Young, W. A., and Volin, M. E., 1948, Wyoming sulfur and gypsum as a fertilizer: U. S. Bur. Mines Prelim. Rept. 9, 7 p.

Click back button (<<) on toolbar to return to text

TABLE 1. Nomenclature of rocks of the Wind River Reservation.

ERA	SYSTEM	SERIES	FORMATION AND MEMBER
QUATERNARY	HOLOCENE AND PLEISTOCENE		Flood plain, slope wash, terrace, pediment, landslide, coluvial, and glacial deposits
CENOZOIC	TERTIARY	Oligocene	Wiggins Formation
		Eocene	Unnamed tuff
			Tepee Trail Formation
			Aycross Formation
			Wind River Formation
			Indian Meadows Formation
		Paleocene	Fort Union Formation
MESOZOIC	CRETACEOUS	Upper Cretaceous	Lance Formation
			Meeteetse Formation
			Mesaverde Formation
			Cody Shale
			Frontier Formation
		Lower Cretaceous	Mowry Shale
			Thermopolis Shale
			Muddy Sandstone Member
			Cloverly Formation
	--?--?--?--?--?--	?--?--?--?--?--?	?--?--?--?--?--?--?--?--?--?--?
	JURASSIC	Upper Jurassic	Morrison Formation
			Sundance Formation
		Middle Jurassic	Gypsum Spring Formation
		Lower Jurassic	Nugget Sandstone
	--?--?--?--?--?--	?--?--?--?--?--?	
	TRIASSIC	Upper Triassic	Chugwater Group: Popo Agie
			Crow Mountain
			Alcova Limestone
			Red Peak Formation
		Lower Triassic	Dinwoody Formation
PALEOZOIC	PERMIAN		Park City Formation
	PENNSYLVANIAN	Middle Pennsylvanian	Tensleep Sandstone
		Lower Pennsylvanian	Amsden Formation
	MISSISSIPPIAN	Lower Mississippian	Madison Limeston
	DEVONIAN		Darby Formation
	ORDOVICIAN		Bighorn Dolomite
	CAMBRIAN	Upper Cambrian	Gallatin Limestone
		Middle Cambrian	Gros Ventre Formation
			Flathead Sandstone
PRECAMBRIAN			Granite, granite gneiss, migmatites.

Click back button (<<) on toolbar to return to text

TABLE 2.- Relative potential for mineral resources in stratigraphic units on Wind River Reservation. (H-high, M-moderate, L-low).

Stratigraphic Unit	Commodity: Oil	Gas	Coal	Phosphate	Bentonite	Limestone & Dolomite	Sandstone	Granite and other stone	Shale and Clay	Tuff and Volcanic Ash	Sand and Gravel	Asbestos	Iron	Gold	Uranium	Gypsum
Flood Plain Alluvium											H			L		
Slope Wash Alluvium											H					
Landslide Deposits											L					
Windblown Sand											H					
Terrace & Pediment Deposits											H			L		
Travertine Deposits																
Glacial Deposits											H			L		
Wiggins Formation																
Tepee Trail Formation										M						
Aycross Formation															L	
Wind River Formation	M	M									M			L	M	
Indian Meadows Formation		M													L	
Fort Union Formation		M	L													
Lance Formation	M		L													
Meeteetse Formation			H						L							
Mesaverde Formation	L	L	H				M									
Cody Shale	M		H						L							
Frontier Formation	L	M-H			M-L		H		L							
Mowry Shale	L	L			H				L							
Thermopolis Shale					M-L				L							
Muddy Sandstone Member	L	M-H					H									
Cloverly Formation	L	M														
Sundance Formation	M	M				L										
Gypsum Spring Formation																H
Nugget Sandstone	M-L						H									
Chugwater Group																M
Popo Agie Formation																
Crow Mt. Sandstone	M-H	M					H									
Alcova Limestone																
Red Peak Formation																
Dinwoody Formation	M															M
Park City Formation	H	L		L		M										
Tensleep Sandstone	H					L	H									
Amsden Formation						L										
Darwin Sandstone Member	L															
Madison Limestone	L					H										
Darby Formation						M										
Bighorn Dolomite						H										
Gallatin Limestone						M										
Gros Ventre Formation						L										
Flathead Sandstone							M									
Precambrian								H				M(?)	L(?)	L(?)		

Click back button (<<) on toolbar to return to text

TABLE 3. - Annual production of petroleum and natural gas on Wind River Reservation, 1932-73[1/]

Year	Petroleum barrels	Petroleum gross value	Natural gas thousand cubic feet	Natural gas gross value
1932	128,097	$80,312	-	-
1933	90,739	48,537	-	-
1934	88,510	47,564	-	-
1935	98,406	54,529	-	-
1936	108,434	58,421	-	-
1937	109,660	60,146	-	-
1938	83,547	45,417	-	-
1939	80,305	41,737	-	-
1940	119,854	54,164	-	-
1941	615,691	305,282	-	-
1942	1,076,101	594,183	-	-
1943	1,578,713	1,091,539	-	-
1944	1,906,414	1,431,516	-	-
1945	2,111,775	1,687,675	65,332	$3,267
1946	3,338,376	3,298,918	110,515	6,631
1947	4,335,671	6,684,442	116,059	9,964
1948	6,042,965	13,330,566	212,841	12,770
1949	3,421,294	7,136,933	244,658	14,679
1950	4,550,101	8,722,529	210,620	12,637
1951	5,363,672	10,318,517	321,966	19,318
1952	4,081,735	7,803,192	768,668	46,159
1953	6,488,969	13,536,999	1,177,364	70,968
1954	7,406,991	15,654,323	1,057,621	63,457
1955	7,144,077	15,295,819	1,002,324	60,139
1956	7,330,540	15,930,308	1,019,561	61,174
1957	8,138,185	19,604,160	754,270	46,648
1958	7,716,792	18,299,826	1,226,520	94,449
1959	7,613,924	17,979,339	1,907,318	161,863
1960	7,561,322	17,989,833	1,798,646	156,068
1961	7,119,286	17,049,300	2,148,765	191,255
1962	6,378,596	15,326,182	2,141,146	229,500
1963	6,408,706	15,483,697	2,521,554	278,648
1964	6,208,575	15,188,222	8,483,694	1,503,364
1965	6,048,044	14,803,359	13,693,250	1,966,289
1966	5,782,390	14,278,539	16,276,785	2,405,768
1967	6,344,745	15,810,486	16,045,059	2,388,002
1968	6,957,779	17,580,220	14,363,463	2,436,815
1969	6,710,281	17,730,403	12,484,550	1,863,697
1970	6,891,738	18,551,056	13,024,907	2,344,724
1971	7,077,254	20,605,510	19,075,216	3,180,821
1972	6,766,987	19,618,697	15,336,584	2,600,401
1973	6,279,639	20,678,906	13,322,427	2,536,377
Total..	183,704,881	419,891,302	160,961,683	24,412,852

1/ U. S. Geol. Survey, Conservation Div., Oil and Gas Leasing Br., Casper, Wyoming (written commun. 1975)

Click back button (<<) on toolbar to return to text

TABLE 4. - Annual royalties from petroleum and natural gas production on Wind River Reservation, 1932-73[1/]

Year	Petroleum	Natural gas	Total
1932	$10,039	-	$10,039
1933	6,067	-	6,067
1934	5,946	-	5,946
1935	6,816	-	6,816
1936	7,303	-	7,303
1937	7,518	-	7,518
1938	5,677	-	5,677
1939	5,217	-	5,217
1940	6,771	-	6,771
1941	38,160	-	38,160
1942	74,273	-	74,273
1943	136,442	-	136,442
1944	178,940	-	178,940
1945	210,959	-	210,959
1946	412,365	$829	413,194
1947	835,555	1,245	836,800
1948	1,666,321	1,596	1,667,917
1949	899,292	4,740	904,032
1950	1,107,579	1,580	1,109,159
1951	1,303,293	2,415	1,305,708
1952	984,123	5,770	989,893
1953	1,697,405	14,290	1,711,695
1954	1,965,064	7,932	1,972,996
1955	1,913,514	7,517	1,921,031
1956	1,992,070	7,647	1,999,718
1957	2,450,520	5,831	2,456,351
1958	2,287,478	11,806	2,299,284
1959	2,247,268	20,233	2,267,501
1960	2,248,685	19,509	2,268,194
1961	2,131,118	23,907	2,155,025
1962	1,915,740	28,688	1,944,428
1963	1,948,026	34,829	1,982,855
1964	1,920,589	155,032	2,075,621
1965	1,881,267	264,926	2,146,193
1966	1,826,825	332,535	2,159,360
1967	2,041,997	327,751	2,369,748
1968	2,322,140	337,762	2,659,902
1969	2,331,836	257,727	2,589,563
1970	2,406,920	323,068	2,729,988
1971	2,663,261	468,432	3,131,693
1972	2,533,883	385,885	2,919,768
1973	2,656,305	370,364	3,026,668
Total	$53,290,568	$3,423,846	$56,714,414

1/ U. S. Geol. Survey, Conservation Div., Oil and Gas Leasing Br., Casper, Wyoming (written commun., 1975)

Click back button (<<) on toolbar to return to text

TABLE 5. - Annual tribal income from petroleum and natural gas leases on Wind River Reservation, 1940-74

Year	Bonus payments	Rental fees	Total
1940	-	$11,740	$11,740
1941	-	-	-
1942	$81,233	16,627	97,860
1943	8,812	13,050	21,862
1944	153,700	23,806	177,506
1945	19,950	31,704	51,654
1946	193,782	19,324	213,106
1947	128,805	28,405	157,210
1948	228,518	53,221	281,739
1949	265,536	79,630	345,166
1950	242,609	82,062	324,671
1951	144,034	97,420	241,454
1952	192,674	32,795	256,469
1953	1,183,936	21,905	1,205,841
1954	769,918	68,447	838,365
1955	826,257	155,722	981,979
1956	2,199,673	174,860	2,374,533
1957	385,023	145,725	530,748
1958	243,274	154,064	397,338
1959	41,330	147,986	189,316
1960	307,959	121,072	429,031
1961	513,745	90,438	604,183
1962	246,459	100,936	347,395
1963	551,514	154,082	705,596
1964	1,232,155	150,357	1,382,512
1965	1,008,863	176,959	1,185,822
1966	221,693	2,412,426	2,634,119
1967	197,051	207,761	404,812
1968	109,025	163,522	272,547
1969	49,365	154,003	203,368
1970	104,847	165,888	270,735
1971	494,284	195,364	689,648
1972	85,452	194,765	280,217
1973	467,225	232,374	699,599
1974	954,717	240,960	1,195,677
Totals	$13,853,418	$6,150,400	$20,003,818

Sources: (Bolmer and Biggs,1965; Bureau of Indian Affairs, written commun., 1975)

Click back button (<<) on toolbar to return to text

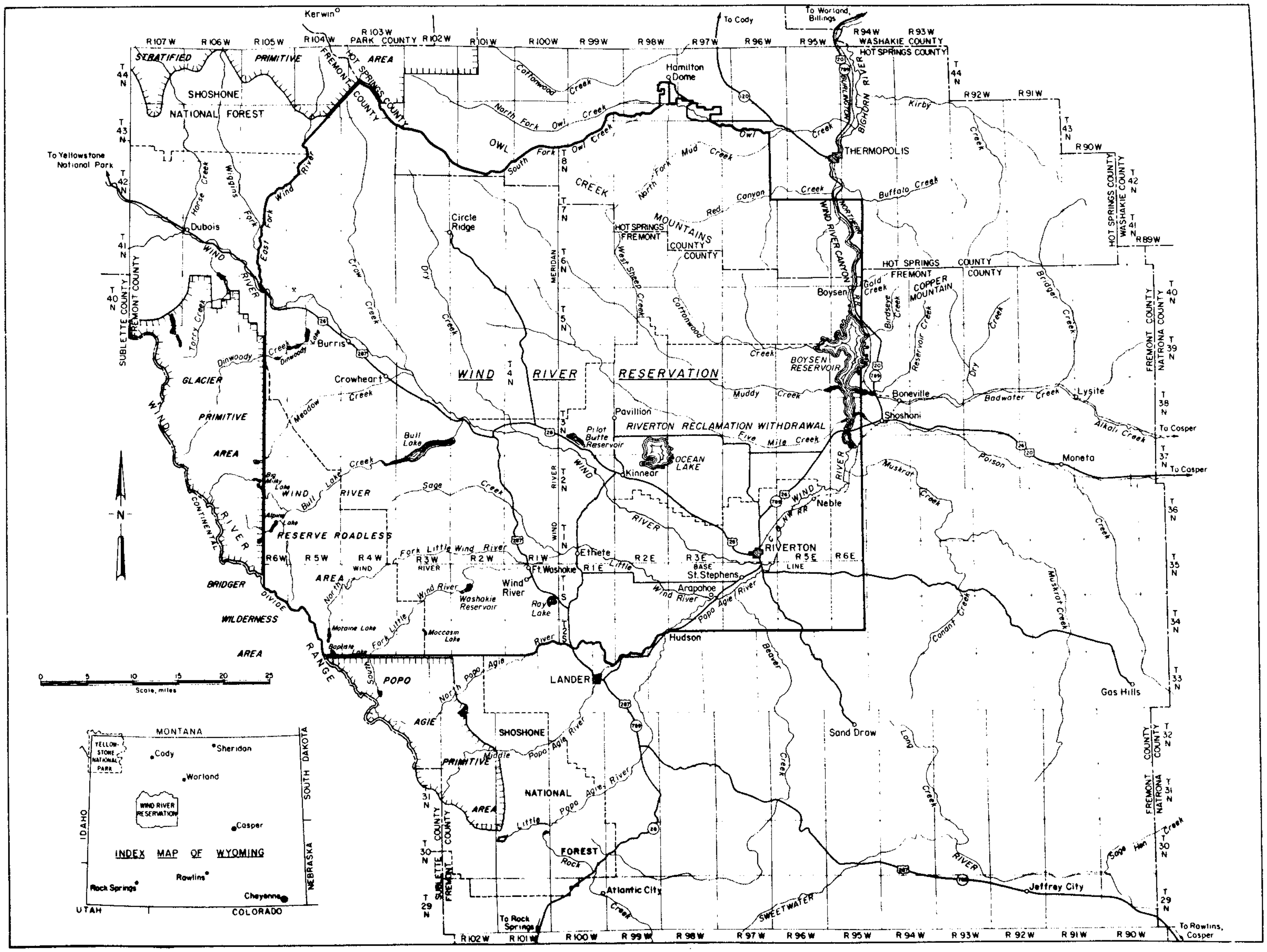

Figure 1. Index map of the Wind River Reservation.

Click back button (<<) on toolbar to return to text

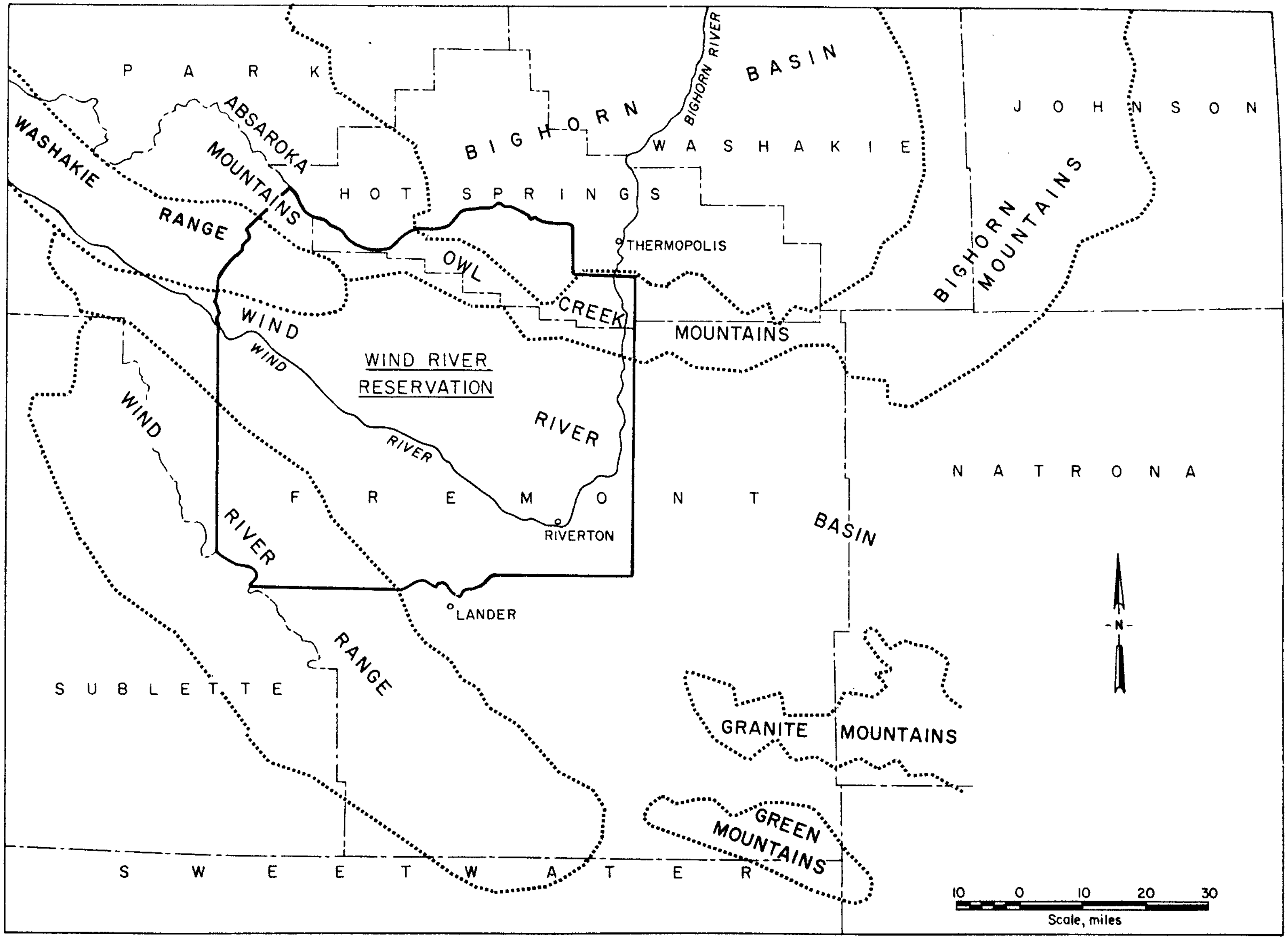

Figure 2. Map showing main physiographic features of Wind River Reservation, Wyoming.

Click back button (<<) on toolbar to return to text

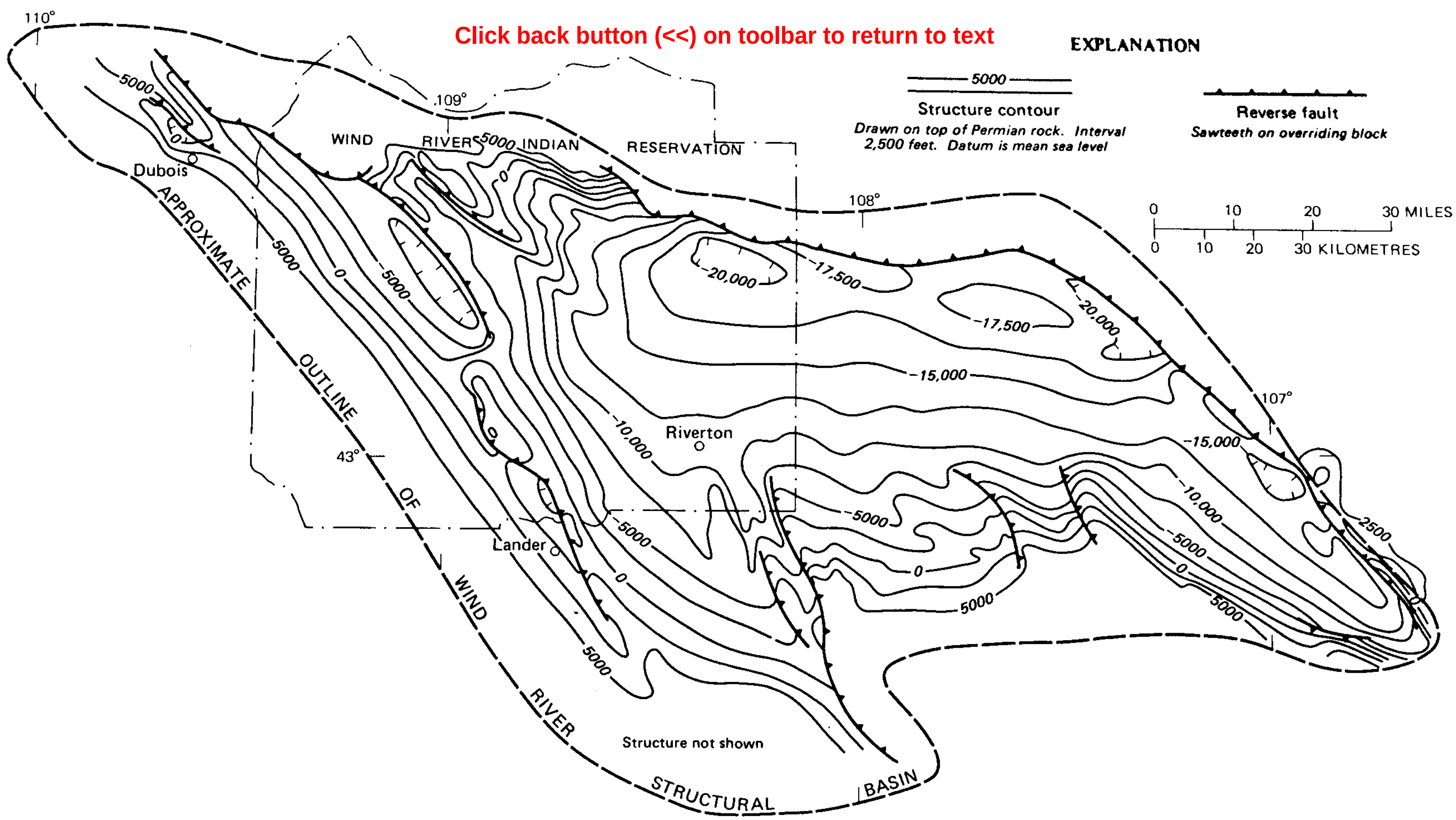

Figure 3. Structure contours of Wind River structural basin (after Keefer, 1969, Figure 1).

Click back button (<<) on toolbar to return to text

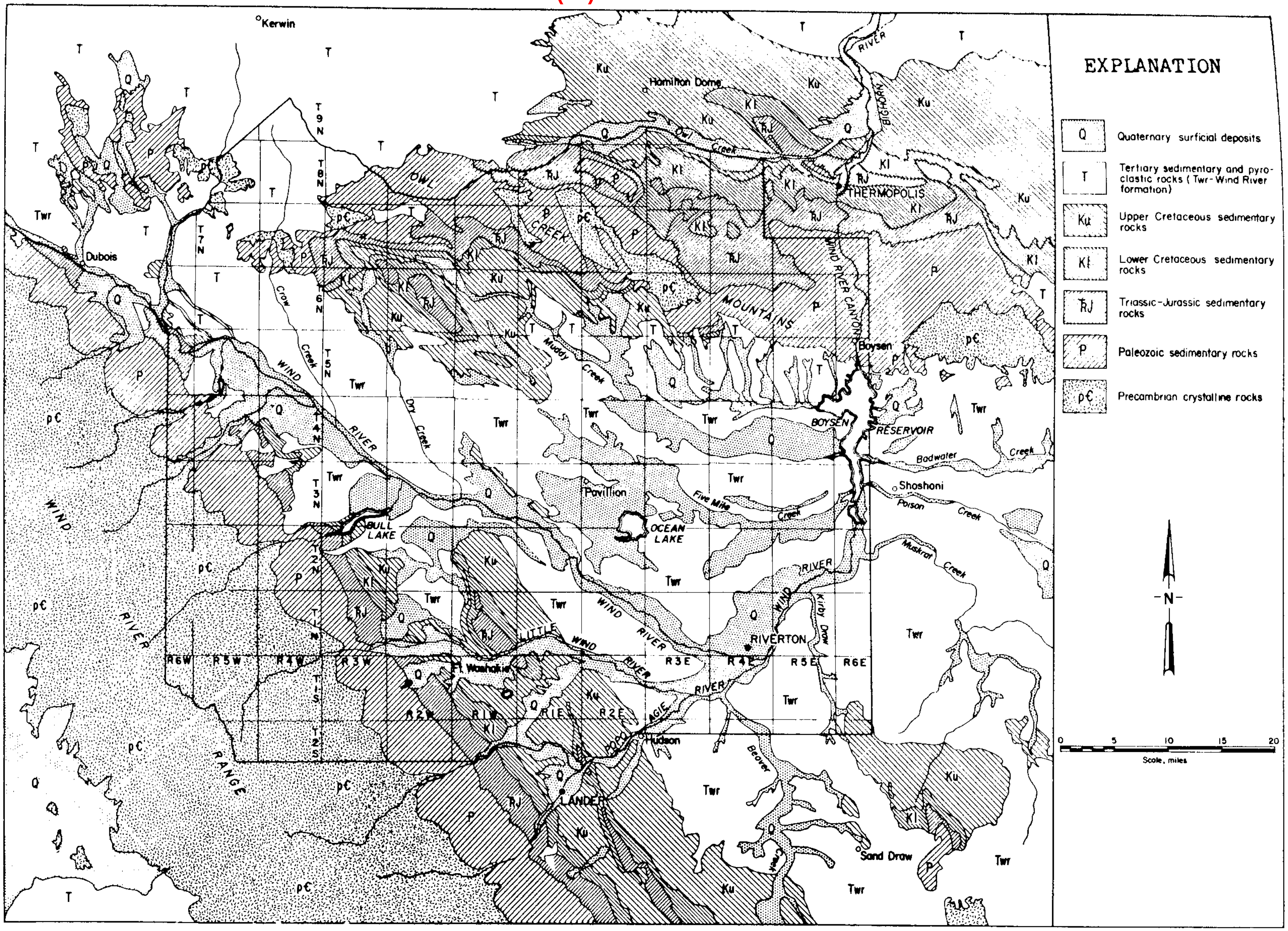

Figure 4. Generalized geologic map of Wind River Reservation (adapted from Geologic Map of Wyoming, 1951).

Click back button (<<) on toolbar to return to text

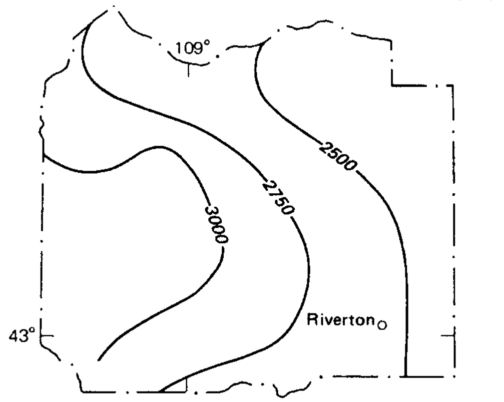

FIGURE 5 A – Thickness map of Paleozoic rocks. Isopach interval 250 feet

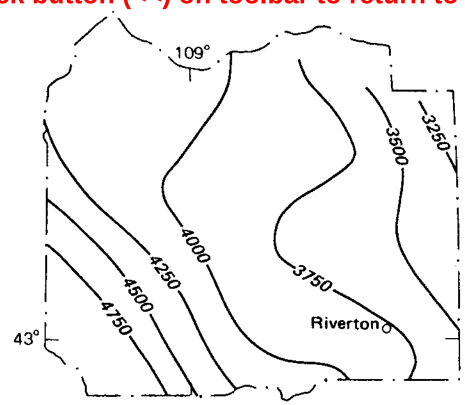

FIGURE 5 B – Thickness map of Mesozoic rocks. Isopach interval 250 feet.

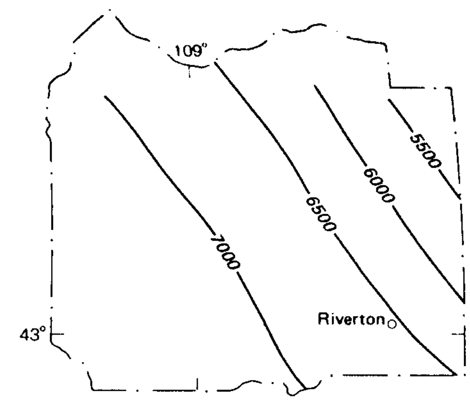

FIGURE 5 C – Thickness map of Cody, Mesaverde, Lewis, and Meeteetse Formations (Upper Cretaceous) Isopach interval 500 feet.

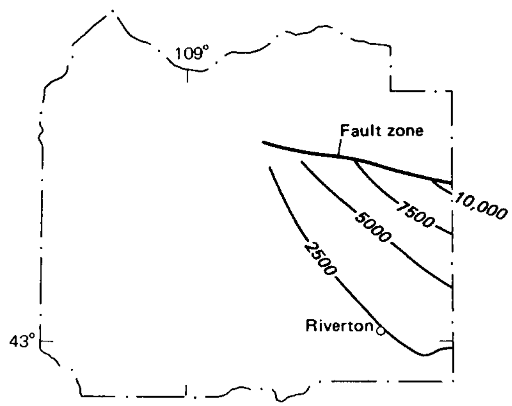

FIGURE 5 D – Thickness map of uppermost Cretaceous (Lance Formation) and Paleocene (Fort Union Formation) rocks. Isopach interval 2,500 ft.

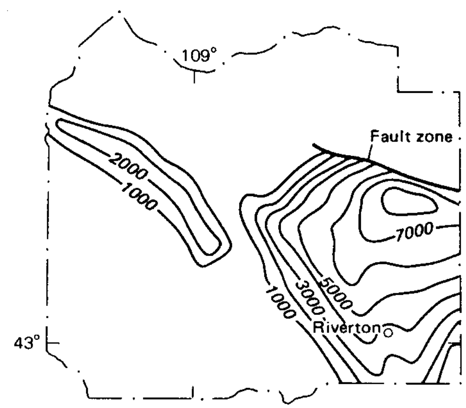

FIGURE 5 E – Thickness map of lower Eocene rocks. Isopach interval 1,000 feet

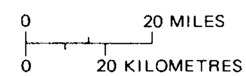

Figure 5. Maps showing thickness of various rock units on Wind River Reservation (after Keefer, 1970).

Click back button (<<) on toolbar to return to text

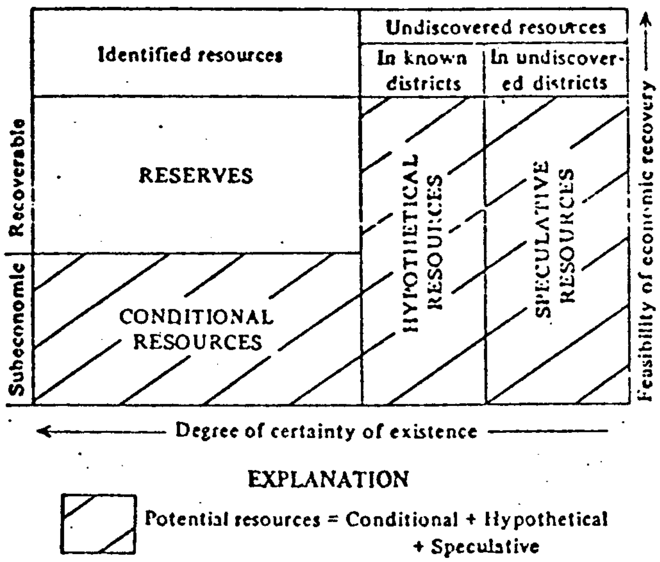

Figure 6. Classification of mineral resources (after Brobst and Pratt, 1973).

Click back button (<<) on toolbar to return to text

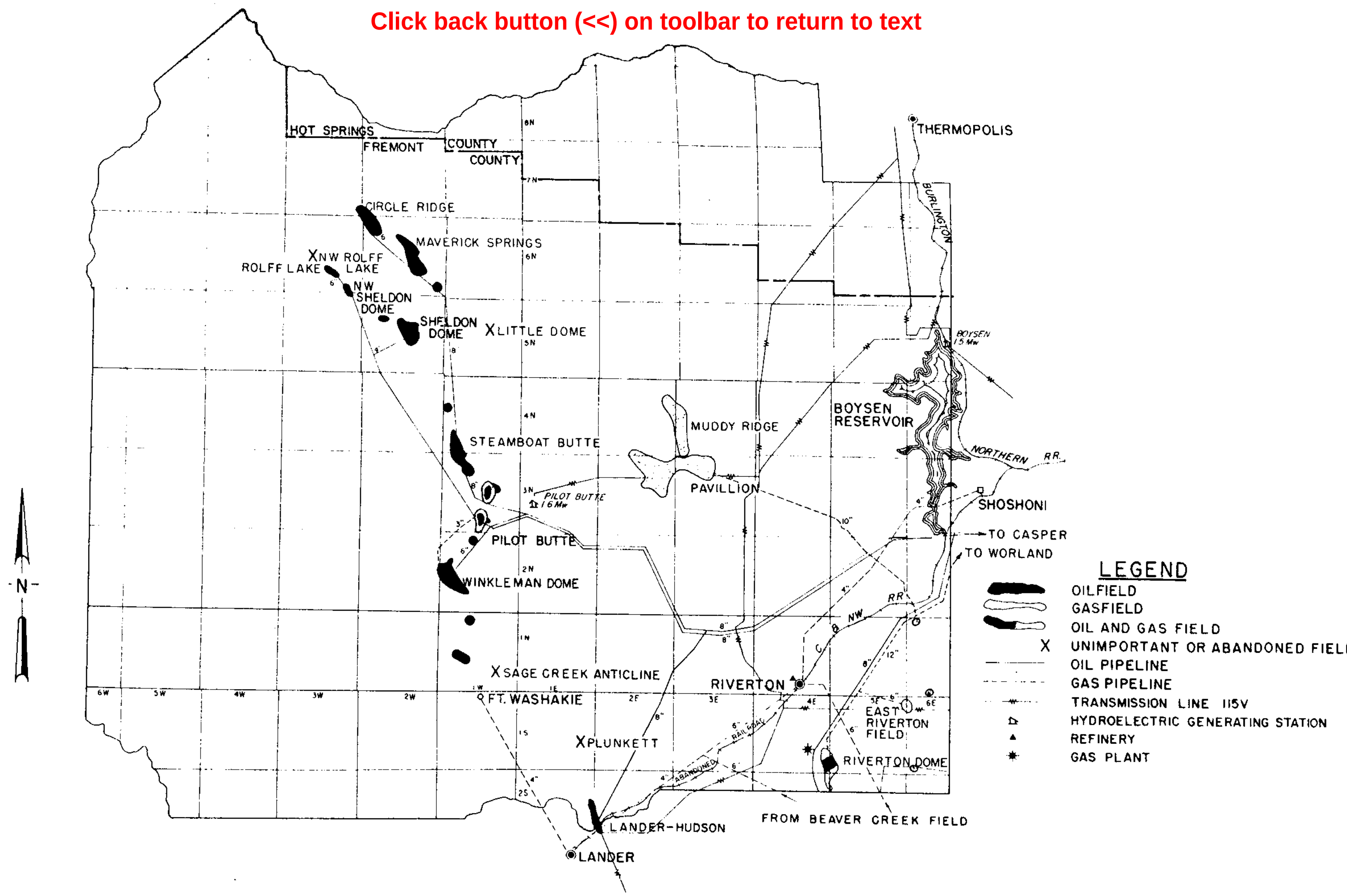

Figure 7. Oil and gas fields and pipelines of Wind River Reservation, Fremont County, Wyoming.

Click back button (<<) on toolbar to return to text

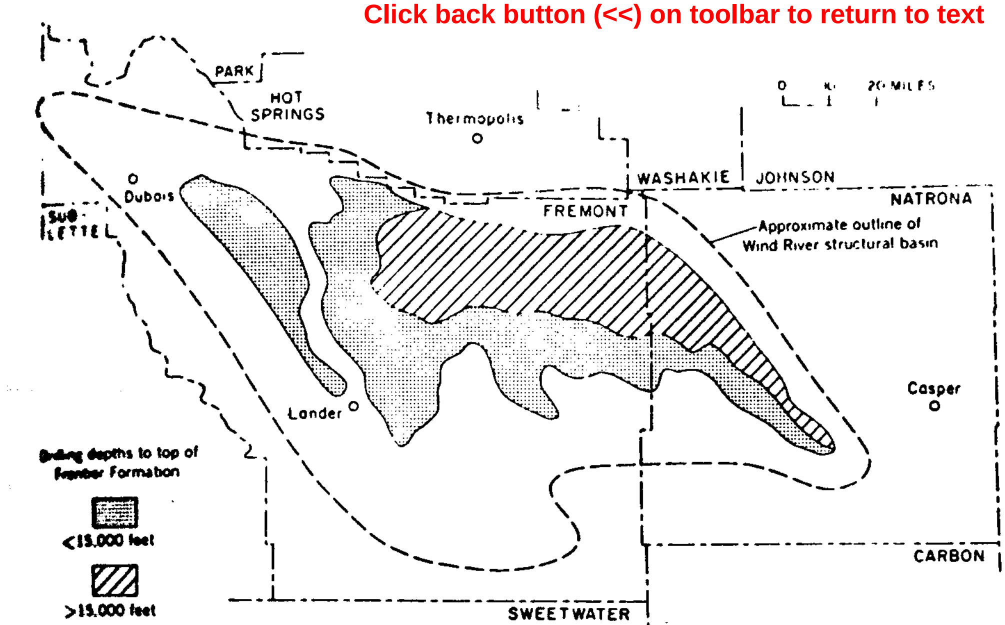

Figure 8. Map showing areas (stippled and hachured) in Wind River basin in which test wells have not penetrated Frontier Formation (Keefer, 1969, Figure 15).

Click back button (<<) on toolbar to return to text

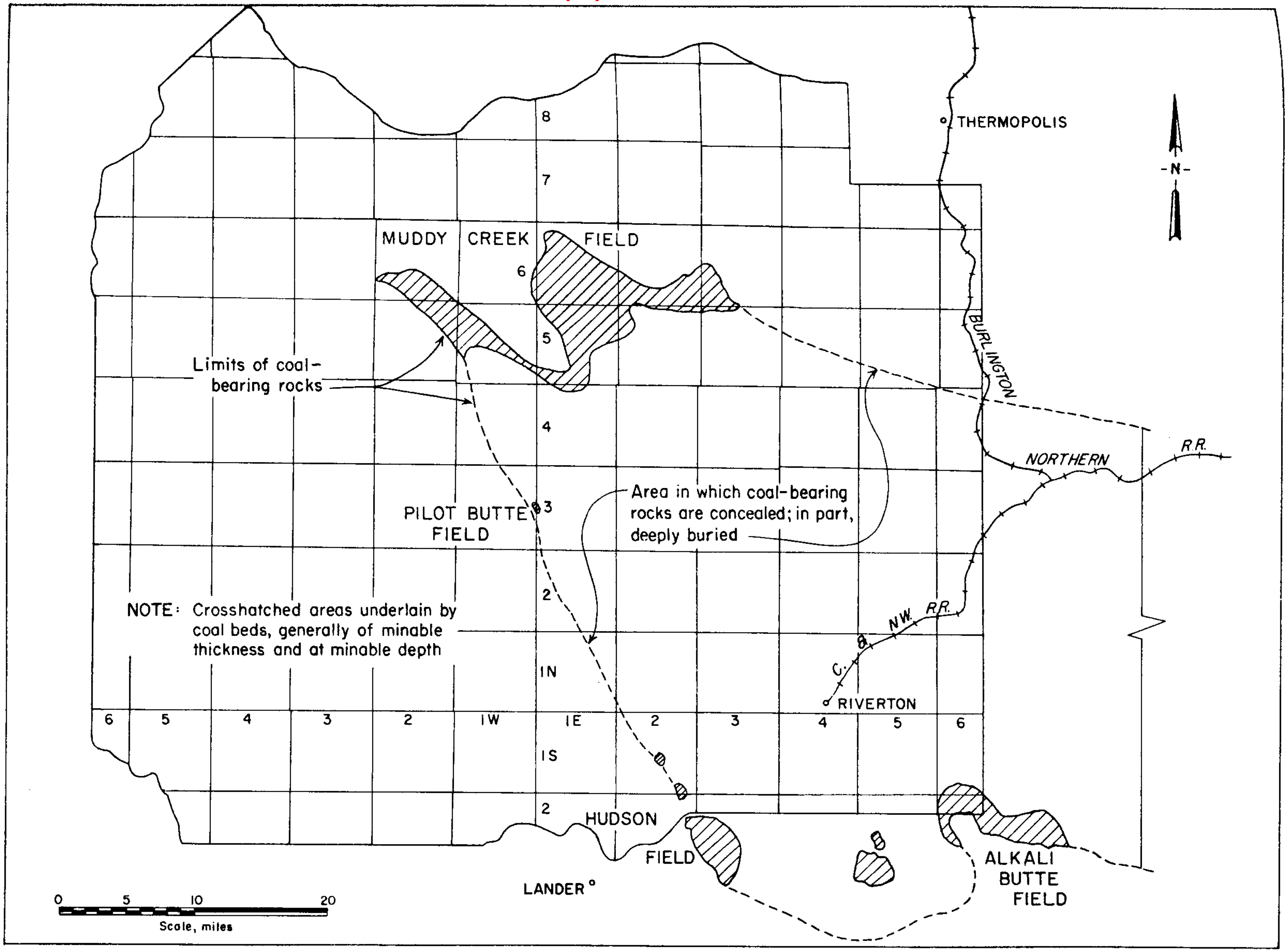

Figure 9. Coal fields of the Wind River Reservation (adapted from Berryhill and others, 1951).

Click back button (<<) on toolbar to return to text

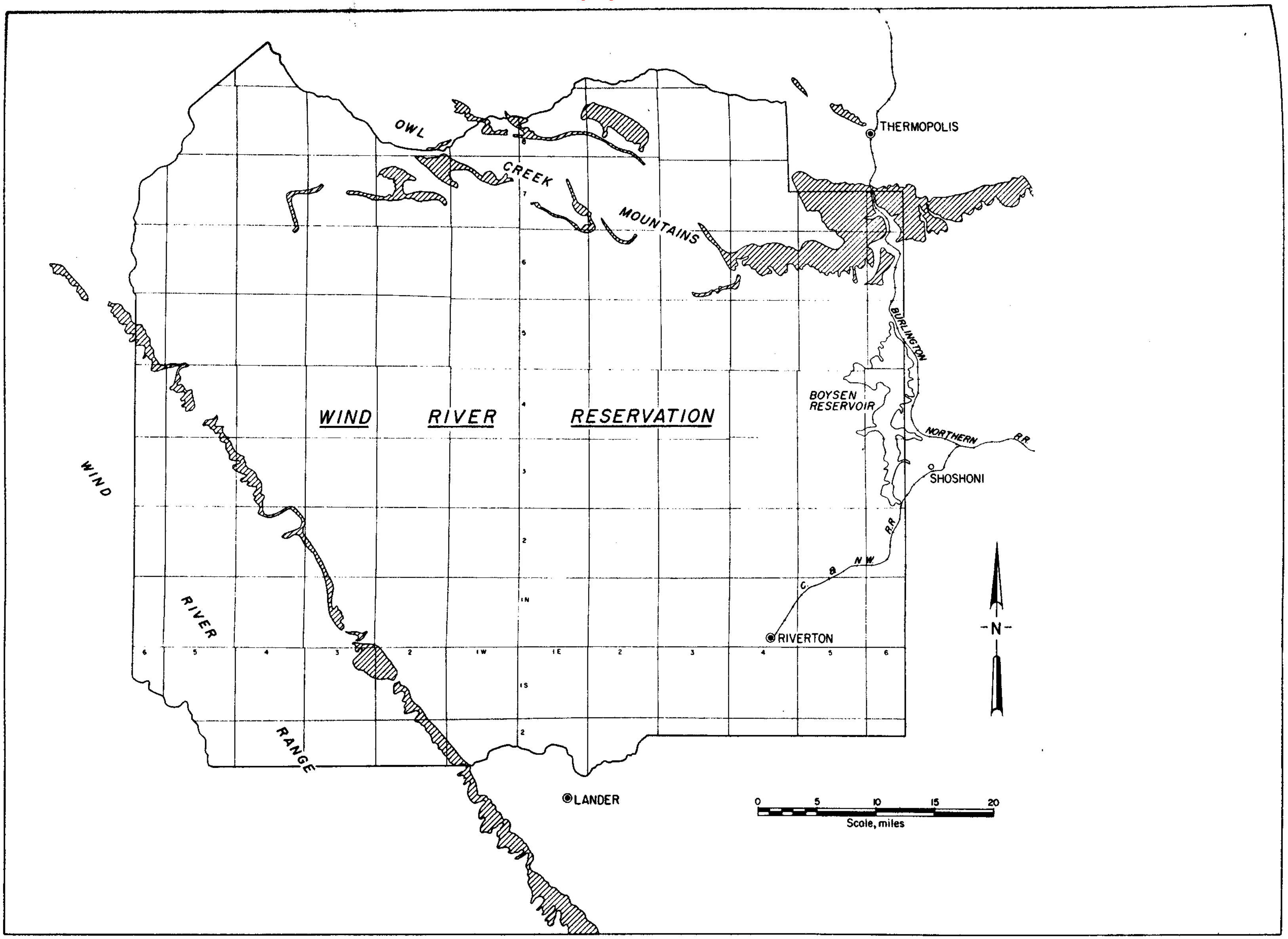

Figure 10. Exposures of the Phosphate-bearing Park City Formation on the Wind River Reservation, Wyoming. (Adapted from U.S. Geol. Survey Geologic Map of Wyoming, 1951).

Click back button (<<) on toolbar to return to text

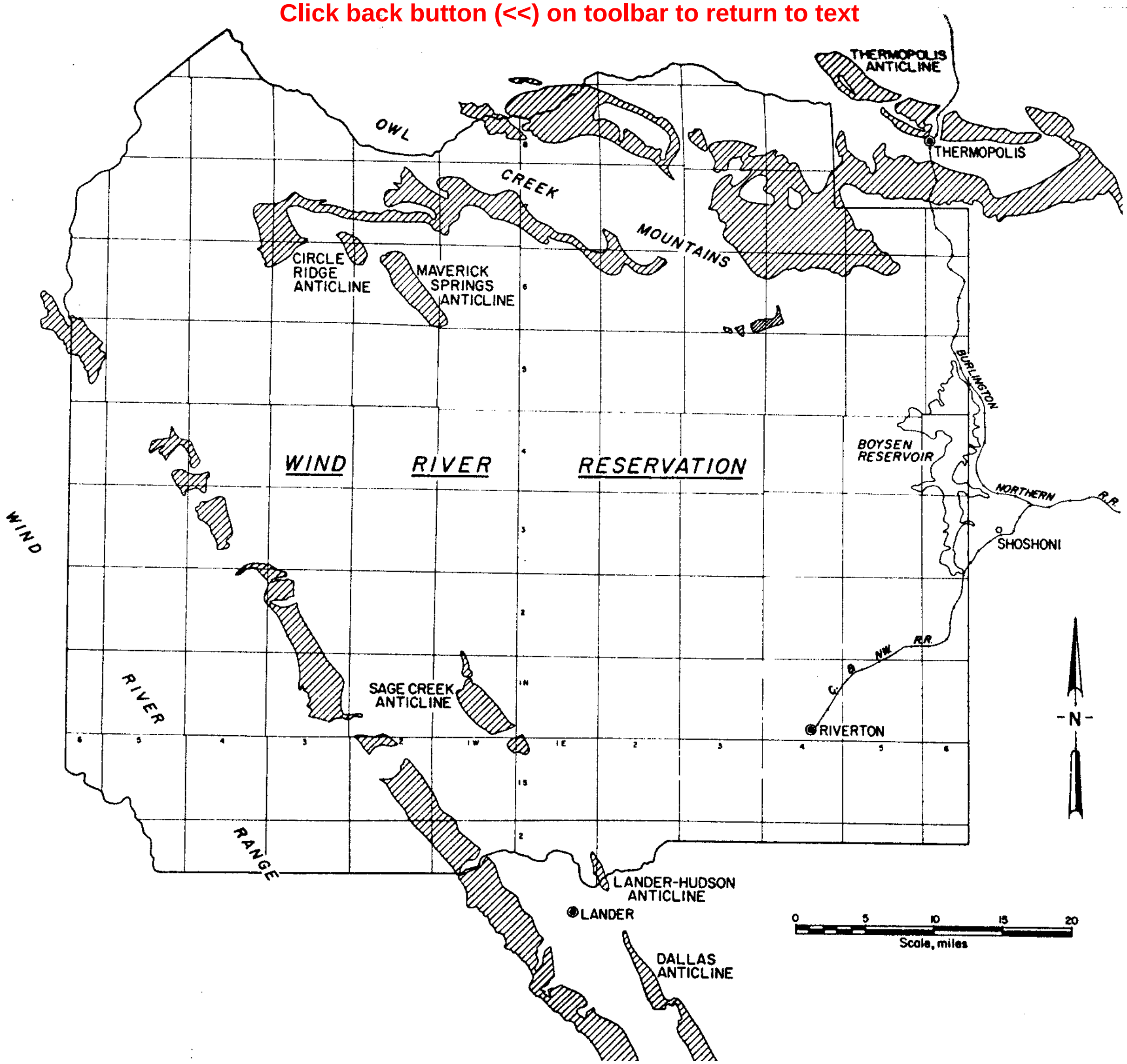

Figure 11. Exposures of gypsum-bearing Triassic and Jurassic rocks on the Wind River Reservation, Wyoming. (Adapted from U.S. Geol. Survey Geologic Map of Wyoming, 1951).

Click back button (<<) on toolbar to return to text

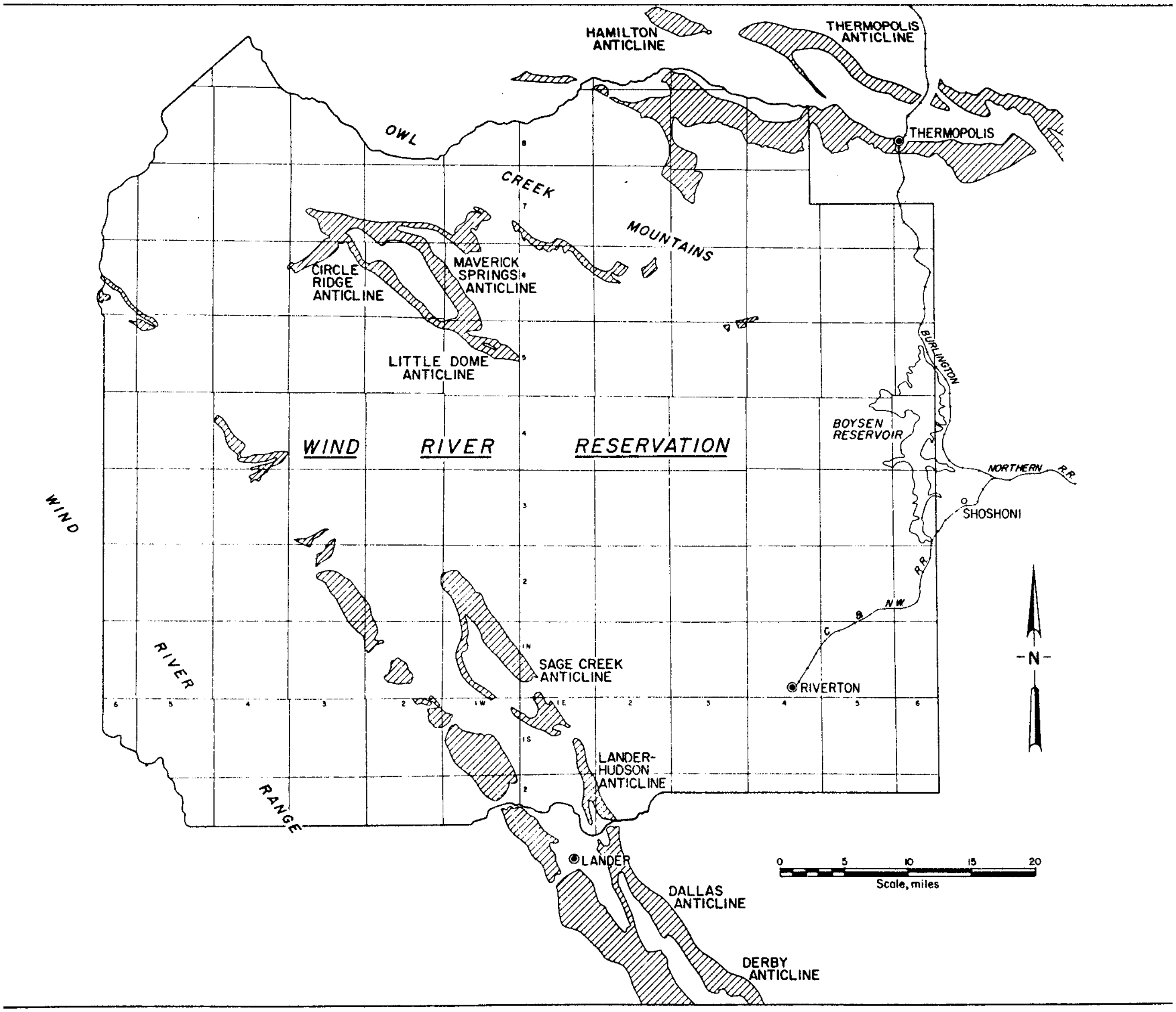

Figure 12. Exposures of bentonite-bearing Thermopolis, Mowry, and Frontier Formations on the Wind River Reservation, Wyoming. (Adapted from U.S. Geol. Survey Geologic Map of Wyoming, 1955).